Sept. 30, 1969 W. D. CORNELL 3,469,454

GOLF GAME APPARATUS

Filed Jan. 9, 1967 3 Sheets-Sheet 1

Fig. 1

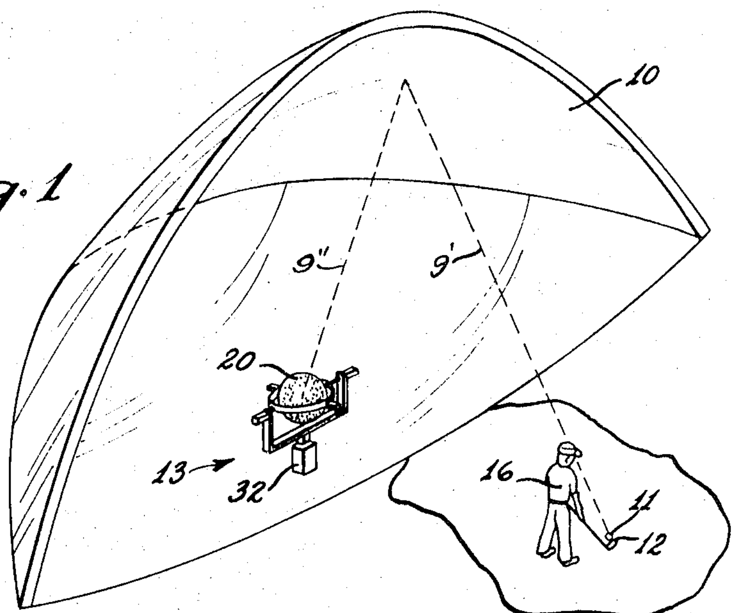
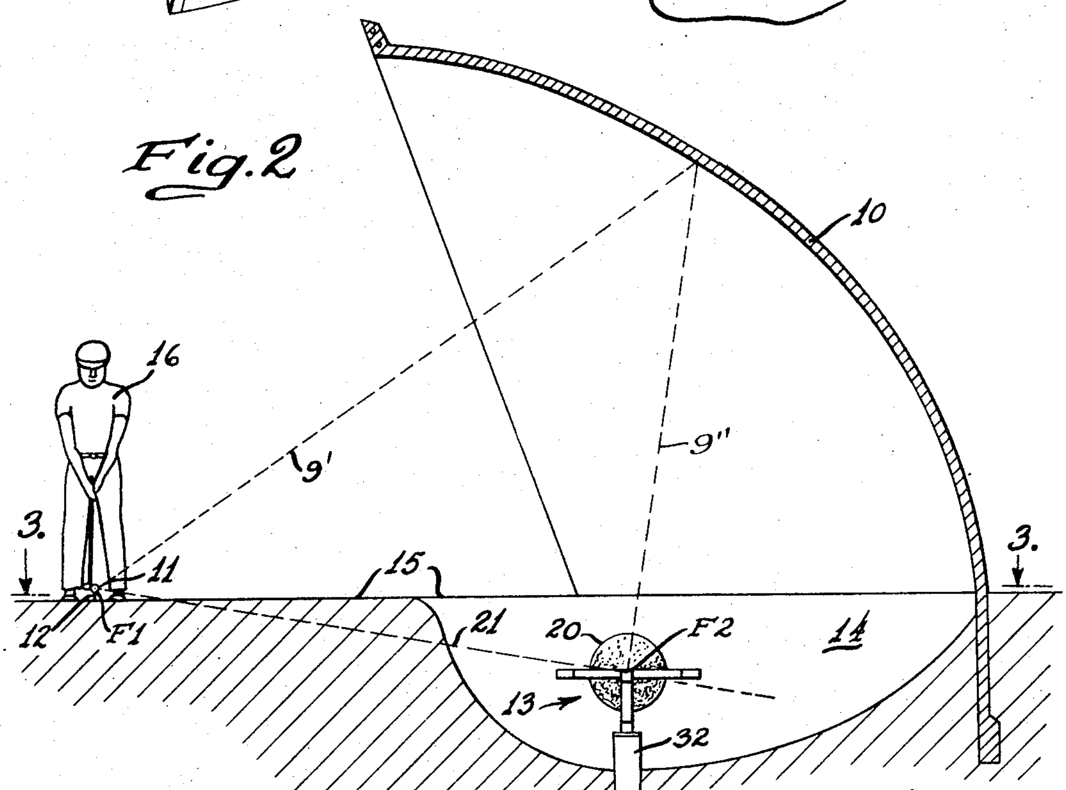


Fig. 2



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GOLF GAME APPARATUS

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Fig. 3

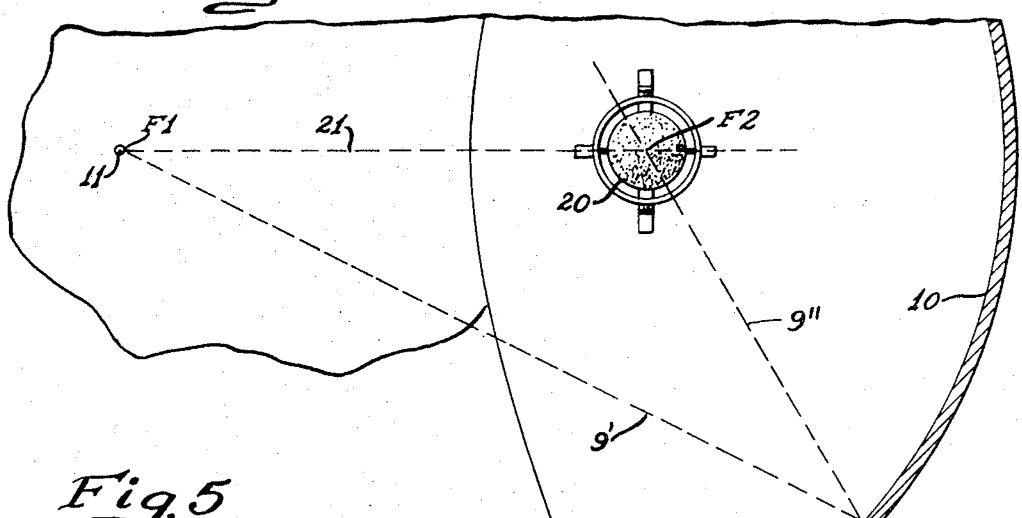


Fig. 5

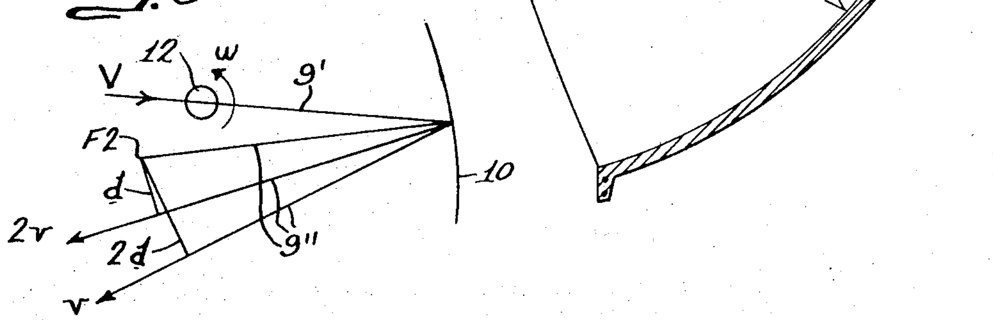


Fig. 4

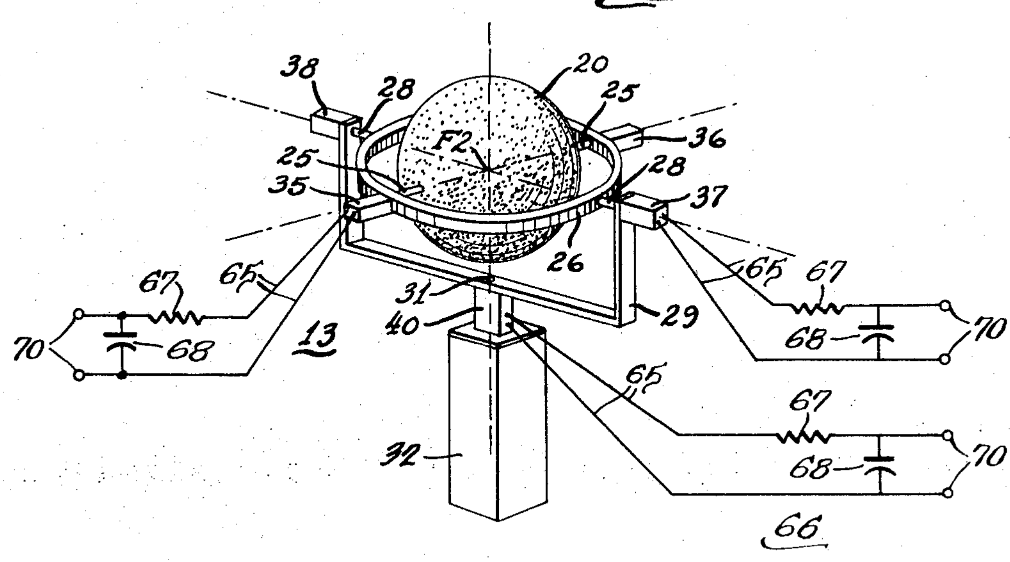


Fig. 6.

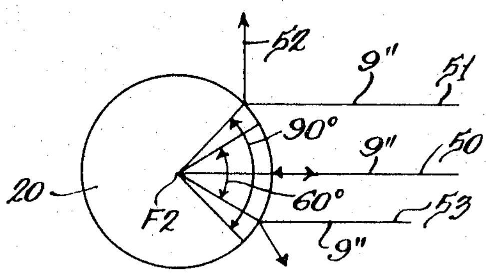


Fig. 7.

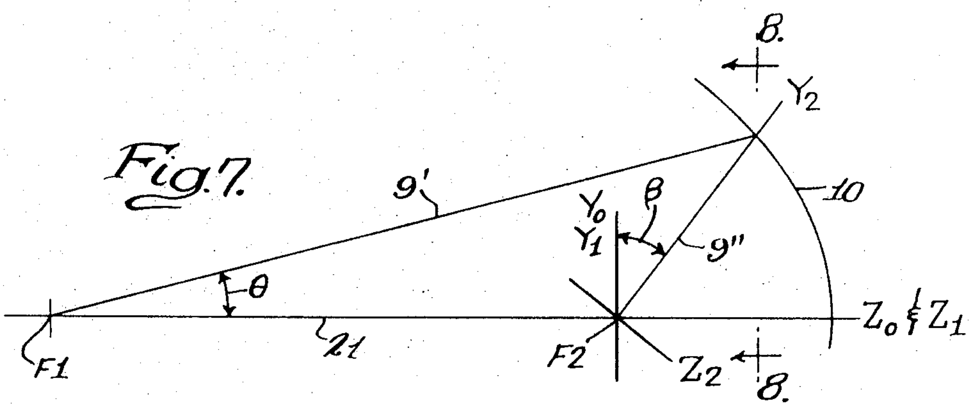
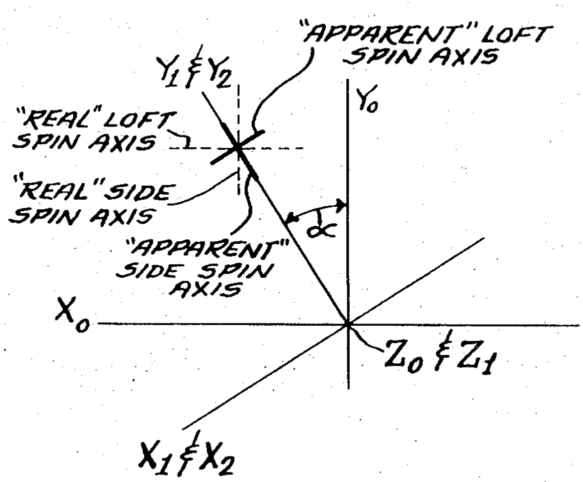


Fig. 8.



United States Patent Office

3,469,454

Patented Sept. 30, 1969

3,469,454

GOLF GAME APPARATUS

William D. Cornell, Grand Haven, Mich., assignor to Brunswick Corporation, a corporation of Delaware

Filed Jan. 9, 1967, Ser. No. 607,930
Int. Cl. G01p 15/00
U.S. Cl. 73—432 17 Claims

ABSTRACT OF THE DISCLOSURE

Spin detecting means for a golf game having a target for rebounding golf balls therefrom including a spherical surface located in the path of rebounding balls together with means associated with the surface for generating an electrical signal when a rebounding ball striking the surface has a trajectory which, when extended, does not pass through the center of the spherical surface so that the electrical signal is representative of the spin on the ball.

This invention relates to apparatus used in a game, and more particularly to apparatus for a golf game that may be played indoors.

Various known golf games for simulating conditions found on a fairway position a target shell to interrupt the flight of golf balls hit from a tee located a short distance in front of the shell. The intercepted golf balls rebound off the shell into an adjacent golf-ball receiver which includes apparatus for determining what the trajectory of a golf ball would have been if the ball had been driven outdoors on a normal fairway. The trajectory depends on both the distance of ball travel and the spin on the ball, which may, for example, cause hook or slice. The applicant's invention is concerned with spin determination. Known apparatus may be used to determine other information about the trajectory.

Prior spin determining apparatus have provided spin information which is in error by an amount dependent on the initial velocity of the golf ball, or the angle at which the ball is driven or hit off the tee, or both. In addition, prior apparatus has been unsatisfactory in determining spin information in a sufficiently short period of time to control a ball spot projector, or similar device, with a sufficient degree of realism, due to the time lag between the time at which a golfer hits his ball and the time at which he observes the results.

In accordance with the present invention, the total spin on a golf ball is determined regardless of the initial velocity or the angle at which the ball is hit from the tee into the target shell. Furthermore, this spin information is available almost immediately after the ball is hit, thereby producing a realistic game.

A principal object of this invention is the provision of a new and improved ball receiver and spin determining means for use with a golf game apparatus.

One feature of this invention is the provision of a ball receiver for use with an ellipsoidal target shell having a first focus point at which is located a tee for the golf balls, and a second focus point at which is located the ball receiver. The ball receiver has a spherical surface whose center point coincides with the second focus point.

Another feature of this invention is the provision of a ball receiver in the shape of a sphere, mounted for universal rotational motion. Motion detectors are coupled to the sphere and have electrical output signals when the sphere rotates, which signals reflect the spin on the golf ball.

A further feature of this invention is the provision of a ball receiver which indicates the total spin on a driven golf ball regardless of the original spin and/or angle of deviation from a desired trajectory.

Still a further feature of the invention is the provision of ball receiver means which indicates the spin on a driven golf ball independent of the initial velocity with which the ball left a tee.

Yet another feature of the invention is the provision of ball receiver means which integrates an acceleration condition in order to produce spin information in a shorter period of time than otherwise possible.

Still another feature of the invention is the provision of a spin detector which is responsive to the momentum of a golf ball rebounding off a target for determining initial golf ball spin.

Further features and advantages of the invention will be apparent from the following specification and from the drawings, in which:

FIGURE 1 is a perspective view of the golf game apparatus, showing the shell and the ball receiver;

FIGURE 2 is a sectional view taken generally through the mid-section of FIGURE 1;

FIGURE 3 is a top sectional view taken along the line 3—3 in FIGURE 2;

FIGURE 4 is an enlarged perspective view of the ball receiver shown in FIGURES 1–3;

FIGURE 5 is a vector diagram illustrating the effect of initial velocity on a rebounding golf ball;

FIGURE 6 is a diagrammatic illustration showing how the size of a ball receiver effects arresting the motion of a golf ball;

FIGURE 7 is a vector diagram illustrating various angular components on a golf ball driven off a tee at an angle; and

FIGURE 8 is a vector diagram taken generally along the line 8—8 in FIGURE 7.

While an illustrative embodiment of the invention is shown in the drawings and will be described in detail herein, the invention is susceptible of embodiment in many different forms and it should be understood that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiment illustrated. The scope of the invention will be pointed out in the appended claims.

The golf apparatus illustrated in FIGURES 1–3 is generally comprised of a concave ellipsoidal shell **10** that is positioned to intercept a golf ball **11** hit in a path **9** from a tee **12** located a short distance in front of the shell **10**. The path **9** of the golf ball, composed of the path **9'** from the tee **12** to shell **10** and the rebounding path **9''** from the shell **10** to within a small area, as will appear, is merely illustrative of one possible trajectory that the ball **11** may follow. The concave shell **10** is arranged with its bottom portion extending below the horizontal level of the tee, and is tilted so that all golf balls hit from the tee **12** towards the shell **10** will impact the surface of the shell and rebound downwardly, regardless of where the balls impact the surface, and towards a small area located below the horizontal level of the tee, between the tee **12** and the shell **10**.

Located at the small area is a ball receiver **13**, constructed in accordance with the present invention, that intercepts the rebounding balls. As seen more clearly in FIGURE 2, the receiver **13** is located in a pit **14** below the ground or floor line **15** on which a player **16** and the tee **12** are located. The receiver **13** has apparatus for generating electrical output signals which are representative of the total spin on the driven golf ball, as will appear. Spin determination is important since side spin on a golf ball will cause a hook or a slice if the ball was driven outdoors on a normal fairway, and backspin, which tends to cause a ball in flight to rise, has a significant effect on the distance the shot will travel. Such spin can be accurately determined without error regardless of the initial velocity or the angle with which ball **11** originally was hit from tee **12** towards shell **10**.

All golf balls driven without spin from the tee **12** towards the target shell will rebound off the target **10** towards a common point of intersection F2. If a golf ball is driven with a spin, the rebounding ball, which strikes receiver **13**, has a trajectory which does not pass through point F2 because the angle of rebound from shell **10** will differ from the angle of incidence by an amount proportional to spin.

The target shell **10** that produces this desired rebounding action is a portion of a surface of an ellipsoidal form whose shape can be seen in FIGURES 1–3. Such a surface may be generated by rotating an ellipse about an axis through its foci, in the manner described in the copending application of William D. Cornell and Donald F. Uecker, "Golf Game Apparatus," Ser. No. 470,363, filed July 8, 1965, now Patent No. 3,364,751, and assigned to the assignee of the present invention. The tee **12** is located at F1, one of the focus points of the ellipse. The receiver **13** is located at or near the second focus point F2 of the ellipse. An ellipse rotated about a longitudinal axis **21** extending through foci F1 and F2, as seen in FIGURES 2–3, will produce an ellipsoidal form, a portion of which is designated as the shell **10**.

As mentioned above, the shell **10** causes all golf balls without spin to rebound towards a common point of intersection, namely F2, and any balls having a spin will not rebound through point F2, but rather will miss point F2. Since a golf ball impacting a massive shell produces an elastic collision in which the angle of incidence is usually not equal to the angle of reflection, it is necessary that surface **10** have a sufficient friction during impact so that the golf ball picks up a spin proportional to its tangential velocity along the surface after impact, and that the coefficient of restitution of the golf ball-shell impact be on the order of 0.72. The reasons and the derivation of these requirements are disclosed in detail in the before indentified copending application, to which reference should be made for a further explanation.

In accordance with the present invention, ball receiver **13** determines the spin on golf ball **12** by measuring, i.e., being responsive to, the momentum of the rebounding golf ball, rather than measuring other parameters such as location. The importance of such a construction will be explained with reference to FIGURE 5, which shows a golf ball **12** traveling along a path **9′** towards shell **10**, and rebounding therefrom along possible paths **9″**, several of which are illustrated.

Prior art spin determining apparatus have often rebounded a driven golf ball off a surface and into a ball receiver. Generally, the spin on a golf ball has been computed in direct proportion to the location of impact of the rebounding golf ball on the ball receiver. The applicant has recognized that the location of impact of a rebounding ball is not a proper measure of ball spin, since location of impact is also affected by other independently varying factors. Rather, the applicant's ball receiver is responsive to an entirely different parameter in order to produce a true indication of the initial spin on a golf ball.

This will be illustrated with reference to FIGURE 5 for a golf ball **12** driven off the tee with an initial velocity V and a spin ω. Three paths **9″** of the rebounding golf ball are illustrated. If the ball is driven without spin, i.e., $\omega=0$, path **9″** passes through point F2.

A different result is obtained when spin ω is some constant value. For an initial velocity of V, golf ball **12** rebounds with a new velocity v along the path illustrated. Spin ω causes this new trajectory to miss point F2 by a distance $2d$, due to the downward deflection of a ball contacting surface **10** with an upward spin. The amount of deflection of a rebounding golf ball is dependent upon the initial angle of impact and the amount of time the golf ball is in contact with the surface **10**.

If golf ball **12** is now hit against surface **10** with the same constant spin ω but twice the initial velocity, or 2V, the golf ball is in contact with surface **10** for approximately only one-half the amount of time as in the previous example. The spin ω has only one-half the amount of time as was previously the case in which to act against surface **10**. As a result, the ball rebounds along a path $2v$ and misses point F2 by approximately the distance d, or one-half the previous distance $2d$ when the ball was hit with initial velocity V.

It will be appreciated that in the limiting case as velocity approaches infinity, the relatively low value spin found on a golf ball was almost no time with which to react against surface **10**, and thus the ball would rebound towards point F2. In these examples, the miss distances and the rebounding velocities are only approximate, since the distances are taken along perpendiculars dropped to skewed lines, and since losses will be encountered in the collision of the golf ball with the target shell. However, it will be seen that the angle at which the golf ball rebounds from any surface is directly proportional to the initial spin on the golf ball, and inversely proportional to the initial velocity of the golf ball. This may be expressed as:

$$\text{Angle of rebound}=f(\omega/V) \qquad (1)$$

that is, as a direct function f of spin ω and as an inverse function f of the initial ball velocity V.

While the distance the rebounding golf ball misses F2, or alternatively expressed, the location of impact relative to some reference line or point, varies with initial velocity, and thus cannot be used for an accurate indication of spin, the product of the rebounding velocity and the miss distance form substantially a constant value. Taking the mass of golf ball **12** as m, it will be observed that the total momentum of the golf balls relative to point F2, for the two examples with constant spin ω, are equal, that is:

$$m(2v)d=mv(2d) \qquad (2)$$

In accordance with applicant's invention, ball receiver **13** is designed to be responsive to the momentum of the golf ball relative to point F2, which is a constant for any given spin ω, regardless of the initial ball velocity V or the angle at which the ball left the tee.

For this purpose, receiver **13**, illustrated in detail in FIGURE 4, has a spherical surface **20** located in the path of the rebounding golf balls. In the illustrated embodiment of the invention, surface **20** forms a complete sphere or ball. Surface **20** is located in the pit **14** so that the center point of the spherical surface **20** coincides with the second focus point F2. The surface **20** is mounted for universal rotation relative to its center point. When a golf ball strikes whose trajectory, if extended, would pass through point F2, the surface will not rotate, since the trajectory is perpendicular to the surface. If a golf ball is driven with a spin, the rebounding trajectory will miss F2, striking the surface at an angle other than 90° and producing a moment about point F2 which rotates the surface about its center point.

The material used for surface **20** should absorb as much of the momentum of the rebounding golf ball as is practical, depending upon the accuracy desired for the spin determination. A material which forms a pocket or depression, such as rubber, or is shaped into pockets, would be suitable to arrest the motion of a ball, as well as a surface having resilient fingers extending therefrom.

The momentum of the striking golf ball, when traveling in a trajectory which does not pass through point F2, imparts an angular impulse to the sphere. This impulse is directly proportional to the momentum of the rebounding ball, such as given for one value of spin by Equation 2.

Since mass m is a constant, the spherical surface is given an angular impulse proportional to the product of the mass distance d and the rebounding velocity v, which, as has been explained, is a constant for a particular constant value of initial ball spin ω. For a different constant initial ball spin ω, a different constant product will be obtained. Thus, the angular impulse imparted to the spherical surface is proportional to only initial ball spin, and not to other parameters such as initial ball velocity.

A rotating sphere has an angular momentum which equals the product of the moment of inertia I for the sphere times the angular velocity ω_a. The angular momentum $I\omega_a$ of the sphere **20** may be expressed as some function f of the angular impulse which caused the rotation, that is:

$$I\omega_a = f(mvd) \quad (3)$$

Since the mass m of a golf ball and the moment of inertia I for a sphere are constants, Equation 3 may be rewritten as:

$$\omega_a = \frac{m}{I} f(vd) = Kf(vd) \quad (4)$$

Where K is a constant. But the function $f(vd)$ is, as has been explained, directly proportional to initial ball spin ω. Thus, the angular velocity ω_a of sphere **20** is directly proportional to the initial ball spin ω which is to be determined, that is:

$$\omega_a = K\omega \quad (5)$$

The applicant therefore determines the angular velocity ω_a of **20**, and produces in response thereto a signal, which signal is directly proportional to the initial ball spin ω, as can be seen by Equation 5.

The detailed structure for producing this signal can be seen in FIGURE 4. A first pair of shafts **25** are rigidly attached to surface **20**, and are rotatably mounted in a first circular holder or frame **26** having a larger diameter than sphere **20**. The frame **26** surrounds the sphere **20** and has a pair of circular openings for receiving shafts **25** therein.

A second pair of shafts **28** are fixedly attached to circular frame **26** and are rotatably mounted in a U-shaped frame or holder **29**. Frame **29** similarly has a pair of openings therein for rotatably receiving shafts **28** such that the axes of shafts **25** and **28** are prependicular to each other in a common plane and intersect at point F2.

At the center of symmetry of frame **29**, a shaft **31** is rigidly attached thereto and is pivotally mounted on a base **32** for rotation relative thereto. The base **32** rests on the floor of pit **14**. Any suitable means may be provided for securing base **32** in place within the pit **14**. For example, base **32** may extend into the ground, as illustrated in FIGURE 2. The arrangement is such that the pivotal axis of shaft **31** also passes through point F2.

From the foregoing it will be apparent that sphere **20** is mounted for universal rotation about three axes, namely the pivotal axes of the shafts **25**, **28** and **31**. Rotation of sphere **20** caused by the impact thereon of a spinning golf ball is resolved into directional components to provide ball spin information.

To provide such resolution, an electrical signal generator **35** has an electrical signal output when a shaft associated therewith is rotated. The housing of generator **35** is rigidly attached to frame **26**, and the shaft of the generator is attached to shaft **25** for rotation thereby. A weight **36** is attached to frame **26** opposite generator **35** to counterbalance the weight of the generator. A similar generator **37** has its housing attached to U-shaped frame **29**, and its associated shaft attached to shaft **28** for rotation thereby. A counterbalancing weight **38** is located opposite generator **35** on frame **29**. A third generator **40** has its housing rigidly attached to base **32**. The output shaft of generator **40** may correspond to shaft **31**, i.e., the output shaft of generator **40** may be directly connected to U-shaped frame **29**.

In operation, if a rebounding golf ball which strikes surface **20** has a trajectory which passes through point F2, no moment arm is formed to cause sphere **20** to rotate about any of its axes and sphere **20** merely absorbs the force of the impact without rotating. However, if the rebounding ball has a trajectory which does not pass through point F2, sphere **20** rotates about any number or all of its axes, rotating the shafts associated therewith to generate electrical output signals which may be used to indicate the spin on the driven golf ball. After sphere **20** has rotated, the weight of generator **35** and counterbalance **36** returns frame **26** to a horizontal plane approximately parallel with the floor line **15** illustrated in FIGURE 2. The golf balls which impact surface **20** fall harmlessly into pit **14**.

In order to be effective, surface **20** must be constructed of a size sufficient to arrest the motion of the rebounding golf balls. For perfect accuracy, it would be necessary that all the momentum of a rebounding ball be expended when the ball impacts surface **20**. However, as a practical matter, such extreme accuracy would seldom be needed, and by allowing some error, the ball receiver **13** can be constructed of smaller size.

Referring to FIGURE 6, three rebounding paths **9″** for golf balls striking surface **20** are illustrated. For a golf ball traveling a path **50** which passes through point F2, the golf ball will strike normal to surface **20** and rebound back along the same path of travel. As the rebounding paths of golf balls deviate from this perpendicular, they will rebound from sphere **20** at an angle other than 90°.

Along line **51**, for example, a golf ball will strike surface **20** and rebound along a line **52** which is approximately 90° from line **51**. This path represents the greatest deviation which applicant has found should be allowed when the sphere is used for spin determination. If a ball is hit further up on surface **20**, the rebounding path would have a component in the same direction as the direction of the rebounding path **9″**, and surface **20** would not have sufficiently arrested the motion of the rebounding golf ball. Path **51** intersects sphere **20** at a 45° central angle, where the normal line **50** is defined as 0°. If this central angle is rotated about normal line **50**, a solid angle of 90° is formed, which represents the sector of sphere **20** which will rebound golf balls at less than a 90° angle from their original direction of travel.

The above may be used to determine the size of sphere **20**. For any given golf game of specified dimensions, it is determined, as by experiment, what the range of most probable paths **9″** will be for a majority of the golf balls rebounding from target shell **10**. Sphere **20** is then made of sufficient size so that golf balls within said range will strike that surface portion of sphere **20** which subtends a solid angle of less than 90°. As a result, the spin determination will be of the desired accuracy for most golf balls. Of course, an occasional misdriven ball, driven for example with a low velocity and a large spin, will strike outside of the portion which subtends the desired solid angle.

In the preferred embodiment of the invention, it is desired that the surface portion struck by golf balls rebounding within a desired range of most probable paths subtend less than a 90° solid angle. Preferably, such balls should not deviate beyond the path **53**, illustrated in FIGURE 6, which forms a 60° angle with the sphere. In such a case, the golf balls will rebound with a component directed opposite to the direction of rebound off the shell. Therefore, surface **20** should be of a size to cause the portion in question to subtend a 60° solid angle. It will, of course, be apparent that the sphere **20** may be made as large as desired in order to obtain any particular accuracy. As the sphere is increased in size, the solid angle subtended by the surface struck by golf balls rebounding within the range of most probable paths will continually decrease in value.

Returning now to the means for determining initial ball spin ω, the angular velocity ω_a is determined by the motion generators, for the reason discussed with relation to Equation 5. The total angular velocity ω_a is broken down into three components, corresponding to the amount of rotation about each of the axes associated with the generators **35**, **37**, and **40**. By a proper transposition of coordinates, as will appear, it is possible to combine the three signals from the generators to produce two mutually perpendicular components which indicate loft and side spin.

While generators **35**, **37**, and **40** may be responsive to the velocity of rotation of their shafts, in order to produce the angular velocity signal which will be transposed, they preferably are accelerometers which generate output signals proportional to the acceleration of their associated shafts. Accelerometers, per se, are well known in the art and it is not deemed necessary to describe their internal structure. The output signals from the accelerometers are integrated, as seen in FIGURE 4, to produce an angular velocity signal about each ball axis. This signal may then be used in the same manner as if the output of the generators was the angular velocity signal itself.

Referring more particularly to FIGURE 4, as a rebounding golf ball strikes surface **20** of the sphere, it will take a finite period of time before the mass of the sphere can be accelerated to a constant velocity representative of the spin on the golf ball. This lag between the time of impact of the ball and the time at which the output from velocity generators would indicate the final velocity, may represent an undesirably long time period, especially when the spin information is used to control a golf game computer and/or ball spot projector, which are known in the art. In such an application, the spin information must be derived almost instantaneously after impact, or an unrealistic game simulation results due to the time delay between the golfer's short and the time at which he observes the results.

To overcome this problem, the motion generators are accelerometers having output signals which are coupled through lines **65** to an integrating network **66** composed of a resistor **67** and a capacitor **68**. The angular velocity output is obtained across lines **70** which are directly connected across the capacitors **68**. The operation of this circuit is as follows. When a rebounding golf ball impacts sphere **20**, shafts **25**, **28**, and **31** are rotated and will reach a velocity proportional to the spin on the golf ball, for the reason previously discussed. Accelerometers **35**, **37** and **40** differentiate the movement of the shafts to produce an acceleration signal on output lines **65**. While the velocity of sphere **20** is increasing towards some constant value, the acceleration is constant throughout this period of time.

The acceleration signal is integrated by network **66** to produce an output on line **70** which again indicates velocity. By making the time constant of the RC network **67**, **68** sufficiently small, a usable signal is obtained on line **70** in less time than it takes to wait for the massive sphere **20** to accelerate to its final velocity. Therefore, an angular velocity signal is available almost immediately after impact.

The integrating network **68** may be located in the same housing as the generators, or may be located at a remote location, such as within a golf game computer. The electrical signals on line **65**, or on line **70** if network **66** is located at the generators, may be coupled through electrical conductors to known types of utilization apparatus. If desired, the electrical conductors may be eliminated and small transmitters of known design may be associated directly with the generators to transmit a signal which may be either the acceleration signal or the velocity signal. This signal, preferably of small amplitude, may be received by radio receivers located adjacent pit **14** .

The sum, in three dimensional space, of the angular

velocity signals from each axis, whether obtained directly from velocity generators or from the integrated output of acceleration generators, represents a spin vector positioned in an arbitrary direction in space. It is conventional to determine ball spin in terms of loft and side spin which deviate a ball either vertically or horizontally, respectively. By the transposition to be dscussed hereafter, the three angular velocity signals may be combined, if desired, to produce spin information in this more conventional coordinate system.

Turning to FIGURES 7 and 8, a diagrammatic vector representation of the ball flight path **9** shown in FIGURES 1–3 is illustrated. "Real" loft spin (overspin or backspin) is defined as that which rotates a ball about an axis parallel with a horizontal line X_0. "Real" side spin (hook or slice) is defined as that which deviates a ball about an axis parallel to the vertical Y_0 axis. The Z_0, which is mutually perpendicular to both X_0 and Y_0 coincides with longitudinal line **21**, thus orienting all three axes with respect to the ellipsoidal shell **10**. Of course, it will be recognized that these axes are called "real" only because they are conventionally used by golfers as a means of describing the flight of their golf ball with reference to the ground they are standing on, and in fact they are no more real than spin defined around any arbitrary set of axes.

The manner in which the angular velocity signals may be combined to produce spin information with reference to these "real" axes will now be derived. The shafts of the angular velocity generators coincide with the X_0, Y_0 and Z_0 axes. Thus, the output signals from these generators correspond to angular velocity about these corresponding axes. This information cannot be utilized directly in the "real" coordinate system since the line of flight **9** for any ball may form an angle from a desired straight line path.

The line of flight **9′** and **9″** for any ball and the major axis Z_0 define a plane, seen in FIGURE 7 as bordered by the lines **9′**, **9″**, and **21**. This plane is seen edgewise in FIGURE 8. Spin about an axis perpendicular to this plane can be considered "apparent" loft spin, and spin about an axis perpendicular to rebounding path **9″** and lying in the plane can be considered as "apparent" side spin, as seen in FIGURE 8.

If an "apparent" loft spin axis is defined as parallel to a line X_2, seen in FIGURE 8, and an "apparent" side spin axis is defined as parallel to a line Z_2, it will be seen that a line Y_2 mutually perpendicular to both X_2 and Z_2 will correspond to rebounding path **9″**. Since axis Y_2 coincides with the ball flight path, the moment of the rebounded ball has to equal zero about this axis as there is no moment arm. As a result, spin output information will be produced only about axes X_2 and Z_2. This is desirable because the final "real" spin output information is similarly to be referenced with respect to only two axes.

The three cordinate axes X_0, Y_0 and Z_0 will now be realigned so that the new Y axis, Y_2, points to the ball impact point on the shell and coincides with rebounding flight path **9″**. The angle that a plane containing the golf ball line of flight **9** makes with a vertical plane including Y_0 is defined as α, as seen in FIGURE 8. The angle that the golf ball line of flight **9′** makes with major axis **21**, when projected on a vertical plane containing Y_0, is defined as θ, as seen in FIGURE 7. For each particular value of angle θ, the golf ball will rebound off shell **10** and rebound along line **9″** at a particular angle β with respect to the vertical Y_0 axis.

If the X_0, Y_0 and Z_0 axes are first revolved about the major axis Z_0 until the new Y axis, defined as Y_1, coincides with the plane containing the line of flight **9′** and **9″** of the ball, then:

$$X_1 = \pm Y_0 \sin \alpha + X_0 \cos \alpha \quad (6)$$

$$Y_1 = Y_0 \cos \alpha \pm X_0 \sin \alpha \quad (7)$$

$$Z_1 = Z_0 \quad (8)$$

If these new sets of axes are now revolved about the X_1 axis until the Y_1 axis coincides with the rebounding flight path 9″, which new position is defined as Y_2, then:

$$X_2=X_1 \quad (9)$$
$$Y_2=Y_1 \cos \beta \pm Z_0 \sin \beta \quad (10)$$
$$Z_2=\pm Y_1 \sin \beta + Z_0 \cos \beta \quad (11)$$

Rearranging terms in order to produce equations in which the second axes are given in terms of the original axes:

$$X_2=\pm Y_0 \sin \alpha + X_0 \cos \alpha \quad (12)$$
$$Y_2=(Y_0 \cos \alpha \pm X_0 \sin \alpha) \cos \beta \pm Z_0 \sin \beta \quad (13)$$
$$Z_2=(Y_0 \cos \alpha \pm X_0 \sin \alpha) \sin \beta \pm Z_0 \cos \beta \quad (14)$$

Since we rotated the Y axis to a new Y_2 which coincides with rebounding flight path 9″, the moment of the rebounding ball has to equal zero along this axis. If we now assume that two angular velocity generators have their shafts respectively associated with X_2 and Z_2 axes, the rotation of the shafts of these generators produces "apparent" loft and side spin signals respectively. The shaft of an angular velocity generator corresponding with axis Y_2 will not rotate to produce a signal with the axes defined in the present manner.

"Real" loft and side spin must be respectively referenced to the horizontal X_0 and vertical Y_0 axes shown in FIGURE 8. Defining the velocity signal output of a generator for any particular axis with which it coincides, by the same designation as the axis, followed by a prime, it is seen from FIGURE 8 that:

$$\text{"Real" side spin}=Z_2' \cos \alpha \pm X_2' \sin \alpha \quad (15)$$
$$\text{"Real" loft spin}=\pm Z_2' \sin \alpha = X_2' \cos \alpha \quad (16)$$

The velocity signal Z_2' is given by Equation 14, with the outputs of the generators associated with the corresponding axes substituted for the axes' designations. The same relationship holds for the X_2' signal, which may be derived from Equation 12. By substituting the same for the terms in Equations 15 and 16, measurements taken from the original axes are obtained, namely:

$$\text{"Real" side spin}=[(Y_0' \cos \alpha + X_0' \sin \alpha) \sin \beta + Z_0' \cos \beta] \cos \alpha \pm (\pm Y_0' \sin \alpha + X_0' \cos \alpha) \sin \alpha \quad (17)$$

$$\text{"Real" loft spin}=[(Y_0' \cos \alpha \pm X_0' \sin \alpha) \sin \beta + Z_0' \cos \beta] \sin \alpha \pm (\pm Y_0' \sin \alpha + X_0' \cos \alpha) \cos \alpha \quad (18)$$

Equations 17 and 18 can be implemented by any conventional analog computer programmed to derive the mathematical functions expressed. Other than the integrated outputs of the accelerometers **35**, **37** and **40**, corresponding to terms X_0', Y_0' and Z_0', only the angles α and β are needed to solve Equations 17 and 18.

Angle α can be determined by a series of generally horizontal photocells extending in an arc concentric above and in front of the tee located at **F1**. Such a set of photocells, in connection with a suitable light source, for determining the angle α with which a golf ball deviates from the vertical are known in the art.

The angle β can be determined from and angle θ illustrated in FIGURE 7. A conventional set of generally vertical photocells, extending in an arc about **F1**, can determine the angle θ. For any given angle θ, there is a unique angle β associated therewith. By geometry, the angle β for each angle θ may be determined for the dimensions of the particular ellipsoidal shell being used. A conventional look-up type circuit, which gives a new output for each input, may be programmed to produce an output signal β corresponding to the input θ. Therefore, both the angles α and β are readily determinable for use in Equations 17 and 18.

I claim:

1. In a golf game having a tee and a symmetrical target for rebounding golf balls driven thereagainst towards a common point, a ball receiver, comprising: spherical surface means; first shaft means fixedly connected to said surface; first holder means rotatably mounting said first shaft for movement about its longitudinal axis; second shaft means fixedly connected to said first holder and extending therefrom; second holder means partly surrounding said second shaft and rotatably mounting said second shaft for movement about its longitudinal axis; third shaft means fixedly connected to said second holder and extending therefrom; third holder means rotatably mounting said third shaft for movement about its longitudinal axis; said holder means locating the center point of said spherical surface at said common point, thereby causing said shafts to rotate when a rebounding ball striking said surface has a trajectory which when extended does not pass through said center point; and first, second, and third generating means respectively connected to said first, second, and third shafts for generating electrical signals when said shafts rotate.

2. The ball receiver of claim **1** wherein said generating means comprises accelerometers.

3. In a golf game including a target for rebounding golf balls driven thereagainst, a ball receiver for the rebounding balls, comprising: a spherical surface located in the path of the rebounding balls; and means associated with said surface for generating an electrical signal when a rebounding ball striking said surface has a trajectory which when extended does not pass through the center point of the spherical surface, said electrical signal being representative of the spin on the ball.

4. The golf game of claim **3** including means mounting said spherical surface for universal rotation about its center point, said generating means being responsive to the rotation of said surface for generating said electrical signal.

5. The golf game of claim **4** wherein said mounting means includes a shaft fixedly attached to said surface and a shaft holder rotatably mounting said shaft for rotation about its longitudinal axis.

6. The golf game of claim **5** wherein said generating means includes an accelerometer coupled to the rotatable shaft.

7. The golf game of claim **3** for arresting the motion of golf balls rebounding within a range of most probable paths, wherein said surface forms an outer convex portion of a closed curvilinear form, said form having a size sufficiently large so that said surface subtends a solid angle of less than 90°.

8. The golf game of claim **7** wherein said solid angle is on the order of 60°.

9. The golf game of claim **3** wherein said spherical surface forms a sphere.

10. In the golf game of claim **3** including a tee for driving golf balls toward said target, and wherein said target has a concave surface which directs all golf balls driven without spin from said tee to rebound from said target, regardless of the point of contact of the ball with said concave surface, towards a common area located between said tee and said surface, and means locating said ball receiver between said tee and said target with the center point of the spherical surface being located within said common area.

11. In a golf game including a target for rebounding golf balls driven thereagainst, a ball receiver for the rebounding balls, comprising: a surface located in the path of the rebounding balls; means mounting said surface for rotation about three independent axes; and means responsive to the rotation of said surface to generate electrical signals indicative of the spin on the rebounding balls.

12. A golf game apparatus for determining the spin on a golf ball driven from a tee, comprising: a target against which a ball strikes when driven from said tee and rebounds towards an area spaced from said tee; a ball receiver having a surface located within said area, said target and said surface having a construction which causes all balls driven into said target without spin to rebound and strike substantially perpendicular to said surface; and means associated with said receiver for generating an electrical signal when a rebounding ball does not strike substantially perpendicular to said surface, said signal being indicative of the spin on the ball.

13. Golf game apparatus for determining the spin on golf balls, comprising: target means for rebounding golf balls hit thereagainst with differing velocities; means including a device having a spherical surface located in the path of golf balls rebounding from said target for producing a condition which is proportional to the spin on golf balls hit against said target means and is substantially independent of the differing velocities of the golf balls; and means responsive to said condition to generate an electrical signal indicative of golf ball spin substantially independent of ball velocity.

14. The apparatus of claim **13** wherein said target means comprises a portion of an ellipsoidal form which rebounds golf balls hit without a spin towards a common point at said device, and said device is responsive to the momentum of the golf balls for producing said condition.

15. The apparatus of claim **14** wherein said momentum responsive device comprises a mass mounted for rotation about said common point.

16. Golf game apparatus, comprising: spin responsive means producing an output which after a period of time is representative of the spin on golf balls; means for differentiating the output of said spin responsive means; and integrating means coupled to said differentiating means for producing in less than said period of time a signal representative of the spin on the golf balls.

17. Golf game apparatus for determining the spin on golf balls, comprising: a target for rebounding golf balls hit thereagainst; a spin detecting device located in the path of golf balls rebounding from said target, a part of said device receiving a velocity proportional to the spin on golf balls rebounding thereagainst; means producing an output proportional to the acceleration of said part; and means integrating the output of said acceleration means to produce an output proportional to the spin on the golf balls.

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