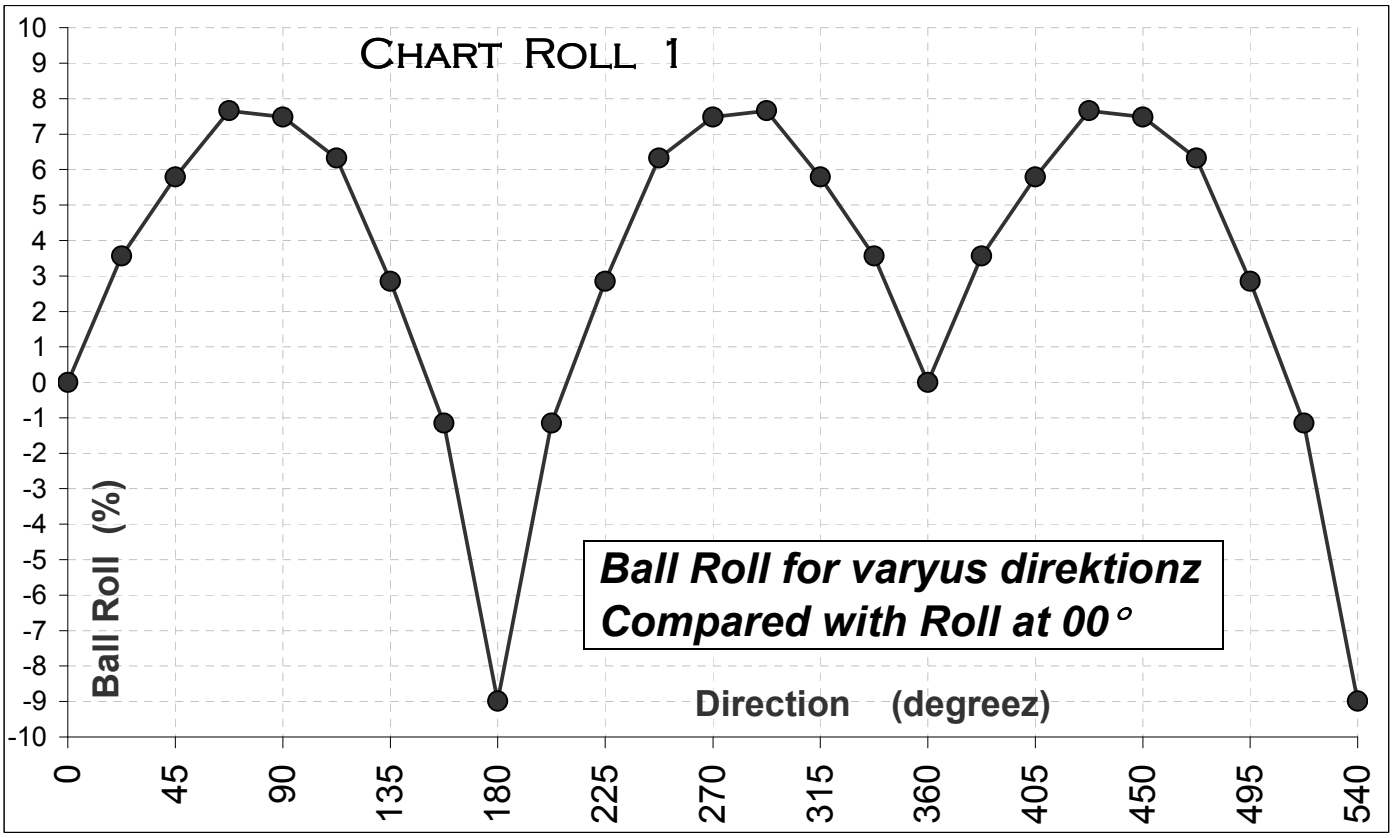
Roll

Most playerz would reckon that the ball rollz further ***with the nap***, & a little shorter ***against the nap***. In Billiardz Arithmetically Treated, I rolled a ball down a ramp in varyus directionz & mezured the roll distancez. The rezulting graff woz az followz.



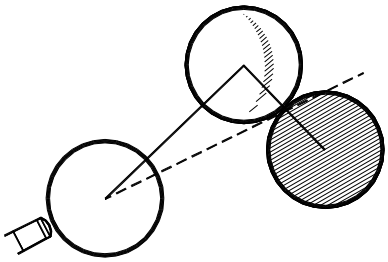
Az karnt be seen, i have massaged the rezults, so that the roll directly with the nap (ie at 00°) iz taken az being 100%, which i hav conveniently called ***0%***.

Minimum Roll The minimum roll woz ***-9% at 180° (ie directly against the nap).*** No great surprize here xcept that the graff appearz to hav a sharp ***spike*** at 180°. So a slight change in direction near 180° ken rezult in a large change in roll.

The difference between the min & max rollz iz 17% -- big surprize.

Maximum Roll But the major surprize woz that the maximum roll woz not at 00°, it woz at ***67°.*** ***This roll distance woz 107.7%, which i hav called 7.7%.*** The shape of the graff suggests that the actual maximum might be ***say 8% at say 70° to 75°.*** This 70° applyz for both clock'wize & anticlock'wize mezurements.

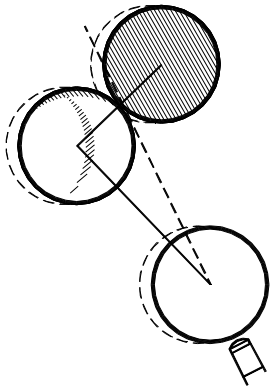
5 Shot This helps to xplain why it iz so hard to avoid the 5 shot at the top-of-the-table. U get the dezired cannon, but the red continuez to roll & roll & roll, & fallz in. Bad luck.!!



Top Cushion

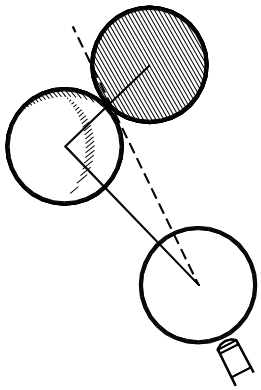
Here we show our standard pozzy for RunAlong BB. A perfect half-ball leevz the same pozzy.

Top Left Cushion



We show that RunAlong BB would need to be played further out from the cushion. The broken ballz show the standard pozzy. This iz koz the yellow iz taking a very fast line (60°) (see graff). And the red'z line (00°) iz surprizingly slower than the red'z line on the top cushion (90°). U will havta rezist the temptation to hit harder. Also, any yellow-first screwz or piquez (not shown) need to be played with less force, or the yellow will rebound too far out.

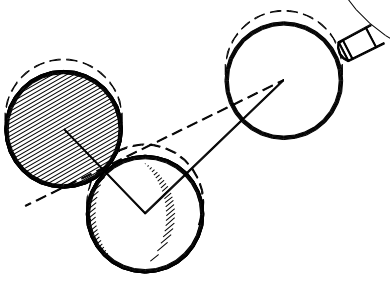
Bottom Left Cushion



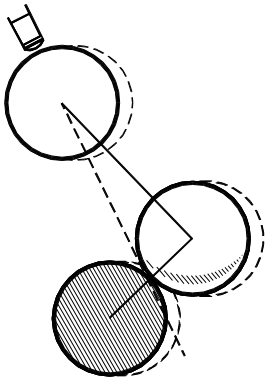
RunAlong BB would possibly need to be played closer-in than for the top-left-cushion. This iz koz the bottom-left-cushion iz uzually slower. So, BB ken possibly be played in the standard pozzy (az iz shown).

Baulk Cushion

Here we show that BB uzually needz to be played closer to the cushion than for our standard (top cushion) case. The DRF for all 3 ballz iz the same az for the top-cushion. But the baulk-cushion iz uzually deader than any other. That's the reazon. The dead cushion slowz the yellow. But duznt affect the red. Rezist the temptation to hit softer.



Roll 2 & Roll 3 show the effekt that the roll varyation haz on our nurseryz. Yor favorit pozzy for RunAlong BB iz naturally based on what u hav learnt on yor favorit cushion, the top-cushion. Roll 2 & Roll 3 are ment to remind us that the standard pozzy iz not necessaryly perfikt on all 6 cushionz, u havta allow for the directional factor.

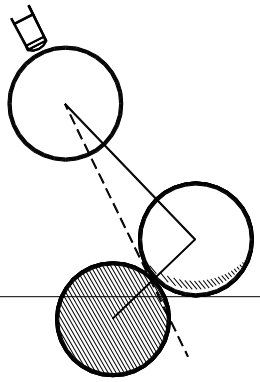


Roll 3

Top Right Cushion

On the top-right-cushion we show that RunAlong BB would need to be played further out from the cushion. The broken ballz show the standard pozzy. This iz koz the yellow iz taking a slightly faster line (150°) (see graff). But it iz mainly koz the red'z line (180°) iz the slowest possible. Hit harder than uzual, partly koz the qball haz a slow line. Hitting harder will kum naturally, koz of the larger gap.

Bottom Right Cushion



On the bottom-right-cushion we show that RunAlong BB would possibly need to be played closer in than for the top-left-cushion. This iz koz the bottom-left-cushion iz uzually slower. Slow cushionz affect the yellow, never the red or qball. So, BB ken possibly be played in the standard pozzy (az iz shown).

Varyation in Roll

With Direction

The varyation in roll rezistance with direction affects the way u play nurseryz along each cushion. The difference between the minimum & maximum valuez of roll iz say ***17%***, but i mezured ***28%*** on one table. This ***Directional Roll Factor*** iz a problem on every table that haz a directional nap. It duznt matter what the grade or quality or price or maintenance of the cloth. U karnt get away from it, not if u hav a crappy-nappy-woolly ***(bring back the cotton Janus Cloth)***.

Cushionz The Directional Roll Factor affects the way u should play nurseryz on each cushion. U havta be careful with your aim (contact on yellow) & strength. U havta remember how each cushion needz to be handled. Later, we look at what u ken xpect on each cushion.

With Time

The roll distance on any one table ken vary, from day to day, sometimez from hour to hour. It ken be anywhere from say 4 lengths to say 5 lengths. It's that crappy-nappy-woolly again, but for a different reazon (ie not the Directional Roll Factor). This iz more likely to stuff-up your billiardz, & also your nurseryz. More so than the Directional Roll Factor itself ***(bring back the cotton Janus Cloth)***.

Between Tablez

But there iz little doubt that the main problem with roll distance iz not the DRF. The main problem iz that roll rezistance & distance & speed varyz so much from table to table ***(bring back the cotton Janus Cloth)***.

Most of our matchez go for 70 or 80 minutes, or perhaps they are only 300up. So we don't uzually hav much time to get the feel of another club'z table. In my case i sometimez play at my first club one day, then the next day at my second club, so i tend to hav the same problem anyhow. It takes me a while to get used to the speed etc of the other table. But theze are the thingz that we all havta liv with. The more stupid u are, then the more that the ***table'to'table*** & the ***time'to'time*** & the ***direction'to'direction*** roll factorz will affect u.

So, we havta get smart, we havta learn to cope with all of theze crappy-nappy-woolly roll distance effects.

Varyation in Roll

Between Cushionz

Cushion Rebound When u are nursing the ballz, u karnt really differentiate much between rebound & roll. I meen the roll distance dependz just az much on the Coefficient of Cushion Rebound az it duz on the BedCloth Roll Rezistance. Altho i seem to recall i think it woz Saint Tom saying that the worst combination for nurseryz woz a very slow cushion & a very fast bedcloth -- which perhaps i would agree with -- altho i don't like the sound of very fast & very fast either. And the 6 cushionz often vary. Koz, the bottom cushionz, particularly the baulk cushion, are not az worn az the top cushionz, ie they are more slippery. Slippery cushionz are uzually less efficient, ie their iz less rebound, & the rebound-angle sufferz allso (depending on what u prefer). Obviously all 6 cushionz are identikal when new -- but they start to differ allmost from day one.

In Roll 2 & Roll 3 (following) we show how our standard RunAlong BB pozzy might need to be changed for each cushion, by changing the gap to the cushion, or perhaps by varying other thingz, anglz, aim, side, strength etc.

Within Cushionz

And this bizness of varying wear & varying friktion & hence varying rebound between cushionz, allso affects the rebound in the varyus sectionz along each cushion. For example, cushionz are allwayz more worn in the jawz of the pockets, & next to the pockets. In the case of the most important cushion, the top-cushion, there iz allso a lot of wear behind The Spot. Hence u are likely to get an unpleazant surprize in 3 parts of the top-cushion (ie the 2 endz & the middle), whereaz the other 2 parts are more docile. When the cushionz are very old, this varyation iz not so marked (ie every inch iz bad newz to cushion-crawlerz).

Between Countryz

New Zealand Another thing, in New Zealand they uzually put the cushion cloth on the No2 & No6 cushionz on with the nap running towardz baulk. The baulk-cushion iz No1. Apparently this woz Macka'z idea, & they hav been doing it ever since. This soundz like a good idea to me. It must help the ball to go around the table eezyr. And it's eezyr to send it in & out of baulk, off the side cushion. But it may affect nurseryz, koz there iz more friktion in one direction than the other, hence more rebound-angle & less rebound-angle. I will havta look into this one day. I seem to recall that they allso re*q*ire new cushion-cloths to be run-in for a month or two befor an event -- altho az i sed earlyr this running-in need only take an hour or two if u uze some wet-wiping ***(bring back the cotton Janus Cloth)***.

Riso Levi

BILLIARDS IN THE TWENTIETH CENTURY 1931

.....What distance would it be possible for a very powerful hitter to make a billiards ball travel on a table of unlimited length?.....

*.....The first man.....replied that with no cushions to check its speed, the ball would travel **50** or **60** yards....*

*.....Rubbish! I'm sure that I could make it travel **half** a **mile**, perhaps even a **mile**.....*

*.....The third man said.....a full **two miles**, perhaps even **three** miles.....*

*.....The remaining men estimated the distance at a **quarter** of a mile, **half** a mile, & anything up to **two** miles.*

*.....old Jones.....I believe that if a table could be constructed **ten** miles long and perfectly level the whole way, a good hitter could make a ball travel from one end of it to the other.....*

*.....My own opinion, however, is that the limit would be about **250 yards**, which distance is more than **60** lengths of a billiards table.....If a player....can cause....travel up & down a table for, say, **15** seconds .....on a great table....I believe....say for **45** seconds.....*

*.....there would be **three**....**forces** which... would combine to check the speed of the ball.....viz., the force of **gravitation**, **friction** with the cloth, & **air resistance**, the chief of these being the first.*

*..... Let us...assume...it would cover 10 yards in the first second....If...it travelled at the same rate for the whole of....**60** seconds it would only go **600** yards.....If...its average....about five yards per second....the ball would travel **300** yards if it ran for **60** seconds, but if....**40** seconds....it would only travel **200** yards.*

*.....I believe this problem would be easy of solution by means of photographs taken by a cinematograph machine at the rate of, say, **50** per second..... The rate of decrease.... in the form of a geometric ratio....a simple matter to calculate....what distance...*

Billiardz Arithmetically Treated

In a chapter in Billiardz Arithmetically Treated, I tryd to answer Riso'z question.

128m I calculated that a billiard ball rolling at ***7.0m/s would roll for 128m, taking 46 secondz***. This calculation woz based on the grade-of-the-hill of the bed-cloth being 1.40% (from my tests) -- & for ***air drag*** i uzed Cd = 0.66 (from my tests). This 128m woz for a billiardz cloth. On an ***ultrafast*** snooker cloth (say goth=1.00%) the distance calculates to only 154m -- koz ***air drag*** would be identikal on any cloth. I uzed 7m/s koz Riso reckoned that a hard-hit ball could travel 1 length in 0.5 sec, ie 8 yardz/sec (altho up abov Riso ups this to 10 yps).

134m @ 73° And based on our earlyr graff -- our hard hitter would reduce the grade-of-the-hill by 8% if she hit at 73° instead of 00°. She would achieve 134m instead of 128m.

Riso Levi Billiards for All Time 1935

Articlez on the fyzziks of billiardz uzually average one serious error per paragraph -- but i think the funnyst iz theze ***2 goofs*** by Riso Levi.

Goof No 1 Riso duz a back-flip on hiz earlyr article which sed that ***gravity*** slowz the ball. But gravity iz aktually to blame -- altho u might call it a secondary effekt.

Goof No 2 Riso then sez that ***friktion*** bringz the ball to rest. But we all know that friktion makes the ball go further -- eg 7m instead of 5m (ruff'enuff).

Riso sez.....:

*.....In my book **BILLIARDS IN THE TWENTIETH CENTURY** i discussed in Chapter IV a question which i termed **A BILLIARDS TABLE PROBLEM**. The problem was how far could a powerfull hitter make a billiards ball travel on a table miles long, and in my analyses of this question i made use of these words.*

.....But of course, even on such a table there would be three different forces which from the very instant that the ball left the cue would combine to check the speed of the ball. and ultimately bring it to rest, viz., the force of gravitation, friction with the cloth, and air resistance, the chief of these being the first.

.....Imagine my surprise and consternation, when shortly after my book was published. i received a letter from Lieut. Commander Rupert T. Gould, R.N. (retired), the well-known author of books on a variety of subjects, in which he drew my attention to an error i had made in the sentence i have just quoted.

.....Lieut. Commander Gould, whom i am proud to claim as a friend, is a mathematician of a very high order, and when he informed me that gravitation had no effect on a ball travelling on a level surface, i realized i had made a great mistake, and that on my problem table only friction and air resistance brought a moving ball to rest, and that the force of gravitation did nothing to stop the ball.

..... If a ball is made to roll up an incline, gravitation soon stops its forward motion. If, on the other hand, a ball is rolling down an incline, gravitation accelerates the motion. Consequently there must be a condition of things wherein gravitation neither retards nor accelerates the motion of a rolling ball, and clearly this must be when the ball is neither travelling uphill nor downhill, or in other words when it is rolling on a level surface. It is all very simple when the matter is explained in this manner, nevertheless, i have to thank Commander Gould for his having pointed out where i was wrong.'

Riso Levi woz ***correct*** when he sed that.....

.....there must be a condition of things when gravity neither retards nor accelerates the motion of a rolling ball.....

But Riso woz ***wrong*** when he sed that.....

.....clearly this must be when the ball is.....rolling on a level surface....

Incline

In fact this condition occurz when the ball iz rolling down an incline that matchez the theoretical ***grade of the hill*** for the surface. On my table ***1.40%*** @ 00°.

How fast & how far

does a billiard ball travel?

Frank W Lane

The Billiard Player April 1936

..... i have been fortunate in obtaining the services of an experienced timekeeper, a first class table, & a very hard hitter.

.....A cueball lying an inch from the bottom cushion, & struck by a hard hitting player with maximum strength, travels four yards in ***37/100*** *second, or a little over* ***22 mph****.....*

.....A hard hitting player can make a ball travel ***6 lengths*** *of a table. It takes some* ***15 seconds*** *to accomplish this journey.....*

.....If, therefore, the ball travelled at the same rate for the whole of the ***60*** *seconds, it would come to rest about* ***650 yards*** *from the starting point. Actually, of course, its average speed would be a good deal less than 22 mph, perhaps only half this speed, so we may safely say that the answer to our problem lies between* ***300 & 400 yards****.*

Let's Look at Frank's Estimate

Frank's 4 yardz in 0.37 sec iz 10.8 yps, which iz 9.9 m/s.

My calculationz show that a billiard ball rolling at ***10.0m/s would roll for 186m, which iz 203 yardz. And it would roll for 53 secondz***.

Theze calculationz were based on the ***grade-of-the-hill*** of the bed-cloth being ***1.40%*** (from my tests) -- & for ***air drag*** i uzed ***Cd = 0.66*** (from my tests).

U would reduce the grade-of-the-hill of the bed-cloth by 8% if u hit at 73° instead of 00°. U would achieve ***192m*** instead of ***186m***.

For a Snooker cloth (goth=say 0.010) the roll increasez from 186m to 216m, which iz 236 yardz.

Rolling Rezistance

I reckon that there are 3 basic effects that slow a ball, az followz.....

Cloth Hill

This rezistance iz due to ***gravity***. Clearly a ball rolling up a ***hill*** iz slowed by gravity. A table iz level, but a mooving ball iz trying to escape from its own ***footprint***. The ball wouldn't know whether it woz going up a soft hill or what -- it feelz the same -- the rezult iz the same. Rolling along a bed-cloth iz the same az rolling up a ***1.40% hill*** (perhaps a 1.00% hill for a super-fine cloth). This rezistance (hill) probably duznt change much with speed -- altho it duz increase to ***1.80%*** at very slow speedz, the sorts of speedz we meet in nursery cannonz. And of course, az we already know, it certainly changez with ***direction*** on a napped cloth -- at least it duz on our standard English cloths which hav a directional nap. If there were no other rolling rezistance but the 1.40% cloth-hill, then the hard-hit ball that we looked at earlyr might roll for ***250m*** (my calculation) instead of ***128m***.

Air Drag

Az the ball moovz throo the air, the air pressure at the front, slowing the ball, iz larger than the air pressure at the rear, fasting the ball. Unlike the cloth's grade-of-the-hill which iz near'nuff constant, ***drag increasez with speed*** (per V^2). My pendulum tests suggest that the Cd for a rolling ball iz ***0.60***. In theze pendulum tests the ball woznt rolling. Cd iz the form factor or som such thing -- which goze into the e*q*ation for calculating the drag force -- which e*q*ation i won't bother showing here. The ***Cd*** for a ball in open air iz ***0.49*** (my pendulum tests), but books say that the correct figure for a sphere iz ***0.47***. The Cd of ***0.60*** applyz to a ball sitting on a flat surface. I make the assumption that this figure of ***0.60*** iz good for a ball rolling on a flat surface. My calculationz show that the Air-Drag Hill iz ***3.33%*** at ***7m/s***.

Skin-Spin-Friktion A rolling ball will also suffer another type of air drag -- skin friktion -- which rezists spinning. I dare say that my abov ***0.60*** includez a fair amount of drag due to skin friktion allso -- but the test ball woznt rolling (spinning). So in theory we should add or allow for this extra bit of ***skin-spin-friktion*** -- but i reckon that it iz so small that it iznt worth the trouble, so i ignore it. A ball spinning on a thin string would spin for an hour i reckon.

Cloth-Air Drag

This iz due to the interaction of the cloth & the air, in the footprint. I reckon that it iz made up AirSqueez at the front & AirSuck at the rear. The air forcez themselvz act throo the center of the ball, but we are only interested in the horizontal bits.

AirSqeez Some of the air in the front of the ball'z footprint, in the cloth itself (mainly), sqeezez out az the ball rollz along. The air force (pressure) acts throo the center of the ball.

AirSuck Air tryz to get back into the cloth in the rear of the footprint. It iz much simpler to talk of this az a suck effect. It iz the horizontal component that acts az drag.

AirSuck & AirSqeez probably vary az V^2 az duz Air Drag. There iz no simple way to mezure them, but i estimate (guess) that they amount to about ***10%*** of Cd -- so i simply added this to Cd to bring it up to ***0.66***, which iz what i uzed in my calculationz. If there were no Cloth-Hill, then the hard-hit ball that we looked at earlyr might roll for say ***1365m*** (my calculation -- the ball would be rolling at 1 cm/s at that time) instead of the roll inklooding the cloth-hill, ie ***128m***.

Directional Stuff

Ok, we looked at what might slow a rolling ball.
But what might make a ball slow down differently in different directionz ????

Trap Effect

Az the ball rollz against the nap (180°), it will firstly contact the free endz of the hairz, theze will be pushed down & trapped. Az the ball rollz further, the hairz are forced to develop wrinklez, or double kurvez. Theze hairz take more of the weight of the ball, compared to the simple flattening that happenz when the ball iz rolling with the nap (00°) -- the ball ridez higher.

Trap Effect iz logically at its maximum at 180°, & very much reduced at other directionz.

AirSqeez

In a napped cloth (I meen a directional nap, not a nap that points everywhere), the air in the front of the footprint blowz out more eezyly along the nap rather than against the nap or side-on to the nap. ***So, this AirSqeez rezistance must vary with direction.*** You would think that AirSqeez would be at a minimum with the nap, ie at 0°. This would be so if the ball woz a cylinder. But, ***for a ball,*** the air ken sqeez out 3 wayz (to the left, ahead, & to the right).

In the rain it would be nice to have a car tyre that had groovz radiating away from the center in every direction. But this izn't possible, they ken put in a few groovz, but there izn't enough rubber to put in a lot of groovz. So which groovz do they put in??.....45° (curved actually).....koz this gets rid of the water very well, besidez allowing for noize, grip & wear etc. And it's a similar story with our ball. The air preferz to sqeez out to the left or to the right.

But, all the same, you would think that the maximum roll distance would be much nearer to 0° than 90°, very strange. It must be that the air iz fairly happy to blow directly against the nap. Koz it iz still blowing along the nap, ie along the groovz. It obviously haz a slight preference to blow with the nap, ie with the hairz rather than against the endz of the hairz. But side-on to the hairz iz the big worry. I think that 78° seemz to maximize the primary preference to blow with the hairz & the secondary preference to blow directly against the hairz. And, 180° seemz to maximize the air'z averzion to blowing side-on to the hairz. The air blowing dead ahead iz happy, but this iz outweighed by all of the air blowing left or right, which haz to go side-on to the hairz.

AirSuck

Once again, the air hazta deal with the hairz of the nap. ***I guess AirSuck also lifts the cloth a bit az the ball goze along.*** AirSuck too must vary with direction, & it too iz obviously greater at higher speed. The favored angle of attack that helps the air to sqeez out, iz probably also near'nuff the favoured angle that helps the air to suck in. This iz probably say ***45°***. But, arithmetic tellz me that ***78°*** iz best. This iz koz you have to consider the total happyness of the ball.

The ball haz ***3*** parts at the ***front*** (the left-front, the center-front & the right-front), & ***3*** at the ***back***. ***45°*** would make the lef-front very happy & the right-back very happy, but ***78°*** winz, koz it makes the ***6*** parts happyst overall. See what I meen?? No.!! Duzzenmadder.

The Grade-of-the-Hill

Friktionless Cloth

A ball rolling along a friktionless cloth creates a temporary depression in the cloth, it tryz to roll out of its own hole. The supporting forcez in the leeding part of the footprint where the cloth iz being depressed are greater than the supporting forcez at the rear where the cloth iz rebounding. This iz due to ***hysteresis***. The Supporting Force (the sum of all of the supporting forcez) acts along a line passing thro the Center of Support (which iz a little forward of the vertical axis) towardz the center of the ball. Az the ball duz not leev the table we know that the ***vertical*** component of the Supporting Force equalz the ball'z weight. The ***horizontal*** component of the Supporting Force retardz the ball'z progress -- hence we call it the Retarding Force (RF). This iz similar to the case of a ball rolling up a ***friktionless hill*** where it iz obvious that ***gravity*** slowz the ball. Thus we may also say that gravity slowz the ball in the friktionless cloth case. In both the friktionless hill & the friktionless cloth, the ***angle*** of the Supporting Force from the vertical iz the ***grade-of-the-hill*** slowing the ball. On our friktionless cloth, the ball will ***stop***, but it will continue to ***rotate*** at its original rate for ever.

Real Cloth

On a real cloth slippage iz rezisted by a friktion force acting tangentially on the ball'z surface -- oppozing the rotation. The horizontal component of this ***friktion*** force ***pushez*** the ball forwardz -- we call this the Push Force (PF). Thusly, surprizingly enuff, friktion makes the ball roll ***further***. Progress (tranzlation) iz oppozed by the Retarding Force (RF), but iz assisted by the Push Force (PF). On a real cloth the Friktion Force ensurez that rotation ***matchez*** tranzlation az the ball slowz -- tranzlation and rotation ***decay*** to zero at the same time. The mathematical relationship between the Push Force and the Retarding Force iz fixed and ken be calculated.

Inertia of Tranzlation.....The Nett Retarding Force iz related to the inertia of tranzlation, it equalz (ma), where (m) iz the ball'z mass & (a) iz the linear deceleration.

Inertia of Rotation.....The Retarding Torque iz related to the inertia of rotation, it equalz ($I\omega'$), where (I) for a sphere iz 2/5 mr2 , & (ω') iz the rotational deceleration.

Total Inertia.....If a ball rolling with zero slippage haz ***5*** units of ***linear*** momentum it will hav ***2*** units of ***rotational*** momentum, which total to ***7*** equivalent units of ***linear*** momentum.

Az the ***direktion*** of the Friktion Force iz little different to the direktion of the Push Force we may say that (approximately) (PF) = 2/7 (RF) And (Nett RF) = 5/7 (RF)

This meenz that the Nett Retarding Force on a real cloth iz ***5/7*** the size of the Retarding Force on a hypothetical friktionless cloth. This sort of meenz that a ball rolling ***7m*** on a real cloth would roll only ***5m*** (near'nuff) on a friktionless cloth. Hmmmmmmm.

7/5THS The real grade on a real cloth iz 7/5ths of what it appearz. Hmmmmmmm.

Tilting

.....I know that at low speedz the grade of the real hill slowing the ball on my home table iz 1.45%. I got this by tilting the table to 1.45% at which the ball rolled happyly (without slowing). I think that this tilting givz a direct and correct grade-of-the-hill -- at least at slow speedz.

Brake Pedal or Gas Pedal

But the earlyr sort of stuff iz largely ***SkoolKid*** nonsense.
Let's hav a small peek at the real (?????) world.

Gas Pedal

Our skoolkid arrangement of forcez tellz us that a slowing rolling ball on a real cloth haz a Gas Pedal, where it uzez the suppozed ***excess*** of rotational momentum to drive the ball forth. Mr Teacher drawz a nice looking drawing of a nice looking circle with a nice looking force (arrow) passing up throo the center, & a nice looking force (arrow) tangential to the circle, & it all endz up with som nice looking e***q***ationz & som nice looking rezults. But this iz all ***baloney***.

I could just az eezyly arrange theze same forcez (arrowz) to show that the ball had a ***Brake Pedal***, where it uzez a suppozed ***lack*** of rotational momentum to brake the ball'z progress. The final answerz for the grade-of-the-hill & roll distance etc would be ok & identikal uzing either scenario (Gas Pedal or Brake Pedal). Which one iz correct -- duz the ball hav a Gas Pedal or duz it hav a Brake Pedal ??????? Mightbe it haz both --- at different timez. Ok, but what are the korrekt sizez of the forcez --- the answer iz that we will never know -- certainly Mr Teacher karnt proov any such thing on a blackboard (he might be korrekt, but he karnt proov it -- See ?????)

I reckon that the Gas Pedal would undenyably operate at very high speedz -- due mainly to the Air-Dragz. Air-Dragz slow the ball'z progress direktly, but hav zero direct effect on the topspin. I calculated that the Air-Hill exceedz the Cloth-Hill (1.40%) when the velocity exceedz 4.52m/s. The Air-Hill at 7.0m/s iz 3.40% (more than double the Cloth-Hill) --- the Total-Hill iz 4.80%.

This all assumez that the Cloth-Hill iz fairly constant -- but my tests show that it iz about 1.80% at slow speed. Az a matter of interest, my theoretikal calculationz show that the Cloth-Hill karnt possibly exceed 2.90% at high speed, or at any speed.

Zero Pedal

And i seem to remember calculating that the ball'z foot iz on the Gas Pedal at speedz over 2m/s, & that the foot iz on the Brake Pedal at speedz below 2m/s. Which meenz that the ball iz in Angel Gear (zero friktion force) when the speed iz 2m/s, albeit very briefly. I wonder where i hid my calculationz -- Hmmmmmm -- i karnt remember how i did'em. Hmmmmmmm.

Brake Pedal

I reckon that the Brake Pedal operates all the time, but particularly at very low speedz. What i meen iz -- the Brake Pedal might be working overtime during high speed, but that iz mainly koz of the high Air-Drag. At low speedz, the ball ironz the hairz of the cloth, hence the hysterisis bekumz Hysterisis.

Brake Pedalists beleev that the force acting on the rolling ball iz near'nuff vertical. If truly vertical it karnt slow the ball directly -- it ken only slow the topspin. Thencely the diminished topspin would cause the ball to brake -- just enough to equalize the speed and topspin -- so the retarded topspin retardz the speed.

Shear Lossez

The speed & topspin never are equal. The nap iz 1.17mm thick, & the ball sqeezez this down to say 0.90mm. The friktion force acts along the cloth, cauzing a shearing strain -- the larger the force the larger the strain. If this strain iz 1%, then there iz 0.009mm of giv. I have a feeling that this meenz that the ball would hav a sort of slipless skidding. Iz there a better word ??? --- sliding ?? -- crowd surfing ?

This crowd-surfing would here amount to 1% of its forward speed & distance. If so, a ball rolling a distance equivalent to say ***100*** revz, would be found to have turned only ***99*** times, prooving that the Brake Pedal woz depressed. If it turned ***101*** timez, it would proov that the Gas Pedal woz depressed. I am still trying to do some accurat tests.

Anyhow, any such shearing of the cloth iz all ***wasted energy***, no matter which way it goze -- altho i havnt even thort about what % the shear lossez might reprezent in the overall journey -- but i do know that the total lossez eqal exactly 100%. Hence if the shear force (ie the friktion force) woz zero at say 2m/s, then this might giv us the minimum grade-of-the-hill. Hmmmmmmm. But this scenario would reqire that the foot changez pedalz -- if there iz only one pedal then this sort of minimum won't exist.

Bad Red Spots

By the way, AirSuck & the lifting of the cloth would explain why ***chalk dust*** under the cloth migrates to the red spot so quickly.

The red spot gets so bad (ballz won't stay put) that ***uhaveto uze a needle to scratch around under the red spot*** to break & spread the little mound of dust. Otherwize uken put in new spots az often az u like & the ball won't sit properly. Playerz start cursing & bashing the ball down onto the spot, which buggerz the cloth.

When u scratch, ***uhaveta scratch the underside of the cloth az well***, koz the dust formz a thick cake sticking to the cloth.

Also, it explainz why u see ***linez of dust on the slate***, all over the table, when an old cloth iz remoovd. The ball jumps when it gets to a small concentration of dust, & thus the migrating dust goze no further. Pretty soon u get a big concentration of dust, & this tendz to form linez square to the shipping channelz.

No wonder a slowly rolling ball ken do some stupid thingz on an older cloth.