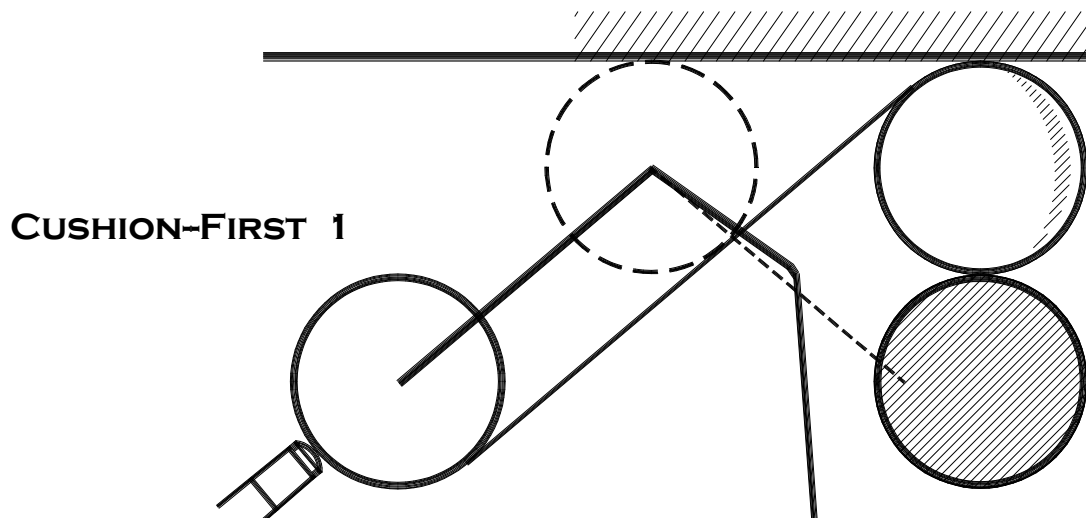


REBOUND ANGLZ

CUSHION-FIRST CANNONZ

Cushion-first cannonz are often the **eezy** way of keeping a Run going. Here we look at a few hints for **judging** the correct **aiming-point** on the cushion. There are a couple of **traps**.



CUSHION FIRST In pozzyz like this, the cushion-first-cannon (shown) ken be a **less risky** sequence than a **direct cannon**. Here the **yellow** iz **frozen** on the cushion, so, we know that aiming to **graze** the left-edge of yellow results in a **thickish** contact on the right-hand-edge of yellow, & the qball then cannonz nicely on **red**.

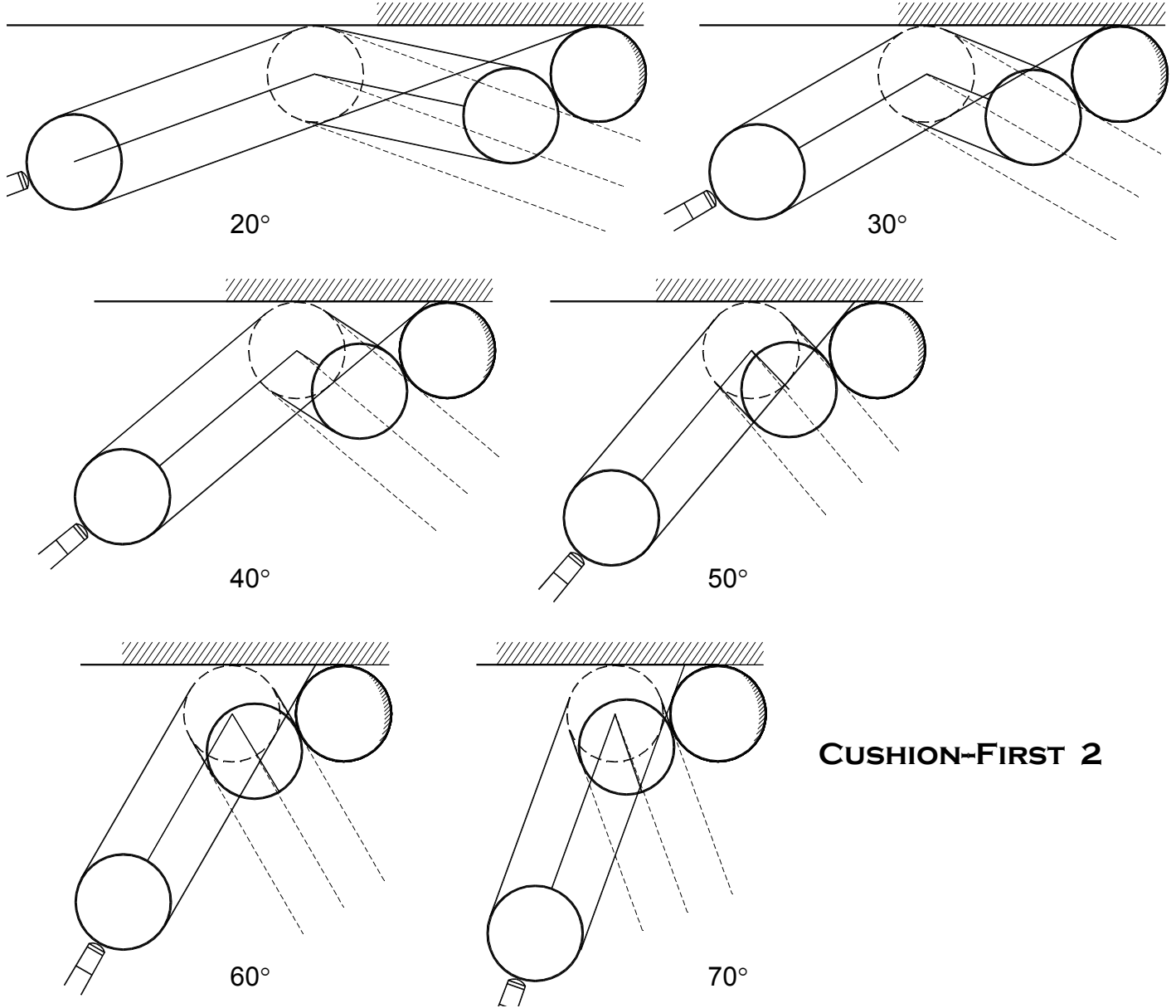
THEORY According to most theoreticianz, practitionerz, & authorz, the qball'z **rebound-angle** equalz the **attack-angle**. So, aiming to **graze** the left-edge of the yellow should result in a **graze** on the right-hand-edge, after rebound. The qball should follow the **broken line**.

ACTUAL But, the **actual** rebound-angle iz **less** than the attack-angle, & the actual rebound iz az shown by the **solid line**. Anyhow, i mezured the rebound-anglz on the right-hand top-side-cushion of my home table, & i got the following rezults. A ball with pure **rolling** woz played very **slowly** onto the cushion at varyus attack-anglz (**against** the **nap**). The **stopping** places were mezured to allow calculation of the rebound-anglz, shown here.

Attack	10	20	30	37	40	50	56	60	70	80	86	90
Rebound	5	12	22	30	33	46	53	59	71	82	89	92
Gain	-5	-8	-8	-7	-7	-4	-2	-1	1	2	3	2

LOSS The **loss** iz greatest when the attack-angle iz between **20°** & **30°**. Rebound **equalled** attack at **65°**. Rebound woz actually **larger** than attack at attack-anglz over **70°**.

VARYATION But cushionz **vary**. Some hav a **newish** cloth covering & hence **slide**, the loss in rebound-anglz iz unbelievable. Some cushionz are **old** & worn (or **high**), in which case the loss would be very **little**. Reading a table iz a necessary part of the game.



CUSHION-FIRST 2

BROKEN LINEZ These drawingz show the rezults of *aiming* for the *left-hand edge* of the *yellow*. The *broken linez* show rebound-anglz *equal* to attack-anglz.

SOLID LINEZ The *solid linez* show the *actual* rebound-anglz (& the qball *contact* on yellow) based on the table of rezults shown earlyr.

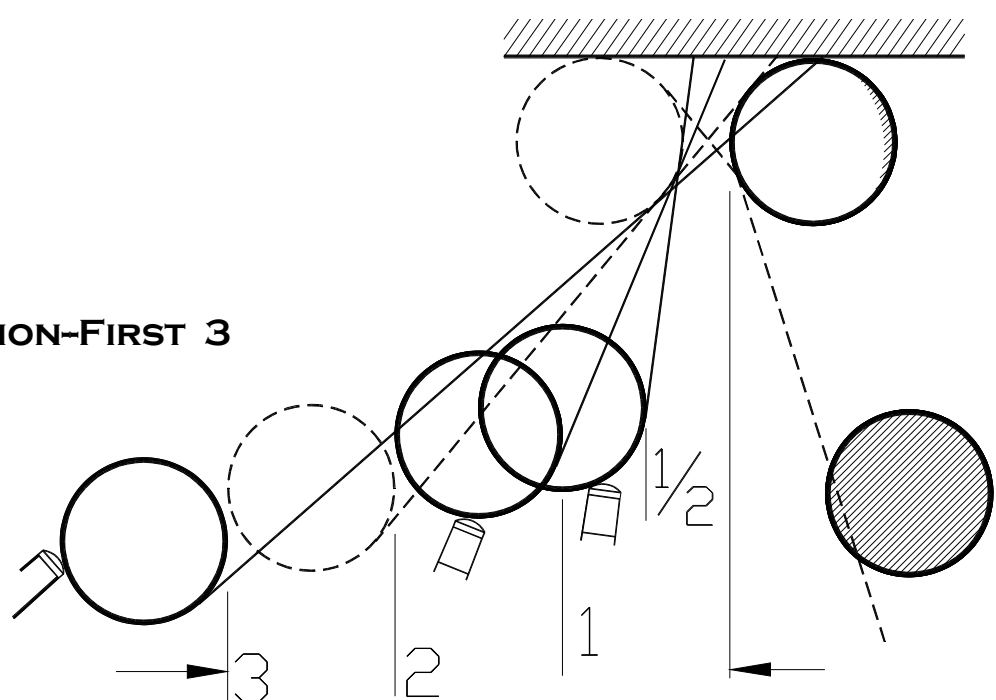
CONTACTS on *yellow*, *mezured* from the abov *drawingz*, are az followz.

Attack Angle	10	20	30	40	50	60	70	80	86	90
Rebound Angle	5	12	22	33	46	59	71	82	89	92
Gain in Angle	-5	-8	-8	-7	-4	-1	1	2	3	2
Contact (64ths)	18	16	9	4	1	-1				

AIM Az karnt be seen, for *narrow* attack-anglz, u might havta *aim* a quarter-ball (16/64ths) *wider* than u might think, if u want a very *thin* contact on *yellow*. And for attack-anglz over **65°**, u might havta *aim* a little *inside* the *yellow*, or u might *miss* the *yellow* altogether.

VARYATION These are the rezults on my home table, which cushionz were neither *slippery* nor *old*. Your table might be different. Actually, i should add that new & old cushionz are uzually pretty *uniform*. Whereaz *medium* aged cushionz are uzually very *varyabl*, the more-uzed sectionz acting like *old* cushionz, & the less uzed bits acting like *new* cushionz. Hmmm. Most playerz don't know what bit them, they don't even know that they were bitten.

CUSHION-FIRST 3



2 BALLZ WEST The *broken qball* iz in *perfect* pozy for a cushion-first cannon, ie 2 ballz *west* of the *yellow*. We ken *aim* for the *edge* of the *yellow* with zero side to get a cushion-first cannon. The contact on yellow *haztabe* very thin koz the *red* iz a little *east* of the yellow. Here, *aim* meenz the *qball* edge line, not centerline.

1 BALL WEST With the *qball* 1 ball west of yellow weken get the same rezult by aiming to hit the cushion at the *same* point az we did for the 2-ball pozy, but with a little *right-hand-side*. This meenz that we havta *aim wide* of *yellow*. Koz if u aim for the *edge* of the yellow (with zero side) u will get a thin touch on yellow but uwill *miss* the *red* (mainly koz the red iz a half-ball east of yellow). Theoretically we could aim say *2mm* wide of yellow (with *zero side*) to get a thinner graze on yellow, & perhaps just get the red, but this would hav given very little *margin for error*. Aiming *wide* with *right-hand-side* iz more *forgiving*.

1/2 BALL WEST With the *qball* only a half-ball west of yellow weken get the same rezult by aiming to hit the cushion at the *same* point az we did for the 2-ball pozy, but with *maximum* right-hand-side. This aiming point *feelz* very wide. Uzing *zero side cannot* possibly giv a cannon in this pozy, no matter how thin u get yellow.

3 BALLZ WEST With the *qball* 3 ballz west of yellow weken try to get the same rezult by aiming to hit the cushion at the *same* point az we did for the 2-ball pozy, but with *lots* of *left-hand-side*. This aim iz well inside the edge of yellow. The left-hand-side (*check-side*) *theoretically* givz the *qball* a *squarer* rebound-angle (ie larger than the attack angle), identical to the *2-ball west* case (& identical to the 1 ball & 1/2 ball casez).

SUMMARY **CUSHION-FIRST 3** showz all 4 shots hitting the cushion in the *same* spot, & getting the *same* rezult (the thin cannon) by virtue of *side-spin* giving each shot the *same* rebound-angle (xcept that we hav zero spin for the two-ball pozy). This iz a good little *trick* to know. But there iz one little *problem*, a little *snag*, a *trap*.

CHECK-SIDE Unfortunately, the *3-ball west* case *duznt* work. Koz, *check-side* haz almost *zero* effect on rebound-angle when the attack-angle iz less than *50°*.

This *trap* needz investigation. So in the *next* section we look at some *tests* uzing *check-side*.

EFFECT OF CHECK-SIDE

Here we look at some test results for cushion rebound using check-side.

PURE ROLLING The following table repeats the test results for pure rolling.

Attack	10	20	30	37	40	50	56	60	70	80	86	90
Rebound	5	12	22	30	33	46	53	59	71	82	89	92
Gain	-5	-8	-8	-7	-7	-4	-2	-1	1	2	3	2

CHECK-SIDE In a second series of tests, we repeated the rebound-angle tests, but hitting the ball with maximum check-side. The following table shows the test results, & the *gained-angle*. The **Nett Gain** is the gain attributable to using check-side, ie the gain over & above any gain that you would have got using zero-side (pure-rolling).

Attack	10	20	30	37	40	50	56	60	70	80	86	90
Rebound	8	13	19	24	28	46	56	66	91	114	124	127
Gain	-2	-7	-11	-13	-12	-4	0	6	21	34	38	37
Nett Gain	3	1	-3	-6	-5	0	2	7	20	32	35	35

PURE ROLLING The first table indicates that, for pure-rolling, the rebound-angle only *equalz* the attack-angle at about 66° (*Hemming would say that reflection equals incidence*). At lesser angles there is a loss, & the *loss* is a maximum (-8°) at 25° . At larger attack-angles there is a *gain*, & the gain is a maximum (3°) at 86° .

CHECK-SIDE The second table indicates that, for check-side, the attack-angle & rebound-angle are *equal* at about 56° . And below 50° check-side is actually *counter-productiv*. And check-side does not really start to justify its use until the attack-angle is over 55° . Anyhow, this mostly contradicts the *skoolkid* theory that you mostly know across.

It should be said that all these tests were done at *slow pace*, the ball usually rolling say 400mm. Also, these tests were done off a *side cushion*, & *against* the *nap*. The pace in the tests was a little faster than the pace at which you would play most close-cannonz, & much slower than the pace at which you would play the average snooker or billiard shot. I haven't yet done any tests at very slow pace or medium pace or high pace (but I have repeated my tests off other cushions).

One shouldn't make too much of these rough tests & figures. Cushions *vary*. The cushions in the tests were not new & therefore not very slippery (I am talking about the cushion-cloths). Logically a new *slippery* cushion-cloth would give different results.

Of course, *running-side* is a different kettle of fish, & I will have to do some extra tests. But there is little doubt that running-side has no surprises for us, so I am in no hurry.

CUSHION-CRAWLERZ are interested in the bits of the above tables between an attack-angle of 30° & 60° . As can be seen, for pure-rolling, the rebound-angle in this zone is always a little less than the attack-angle, & *check-side gives almost zilch nett gain*.

This iz the 2nd most sensible book uken find on the fyzziks of billiardz. Dealerz sez

..... **Cushion Angles** -- *There is a popular fallacy to the effect that when a ball, played without 'side', impinges on a cushion, 'the angle of reflection is exactly equal to the angle of incidence'. As a matter of fact **this is very rarely the case**, the divergence of the ball from its predicted path depending on its own rotation and pace, and on the nature of the angle of incidence.*

..... Mr Hemming states that the line OF fairly represents the path of the ball if struck with No 3 strength and perfect rolling, provided that the angle EOP is not very large. He finds that the angle of reflection is abnormally **increased by** (i) increase in the angle of incidence at a strength below No 3, and (ii) 'follow' on the ball : while the angle of reflection is **diminished by** (i) high velocity at a small angle of incidence, and (ii) defective rotation, or drag.

..... **Side -- Effect on Cushion Angles** -- *The most obvious effect of side is the alteration which it produces in the angle of reflection from a cushion. This effect is most marked when the cushion is played at directly (at an angle of 0°), when a variation of 25° or so is easily produced. At oblique angles the effect of side away from the cushion is to **increase** the angle of reflection, so that the ball travels closer to the cushion.*

*When side towards the cushion is put on, the angle of reflection is generally **diminished**, but when the angle of incidence is about 45°, the angle of reflection seems to be **almost unaltered by cushion side** -- at any rate, in the case of gentle strokes.*

RISO LEVI

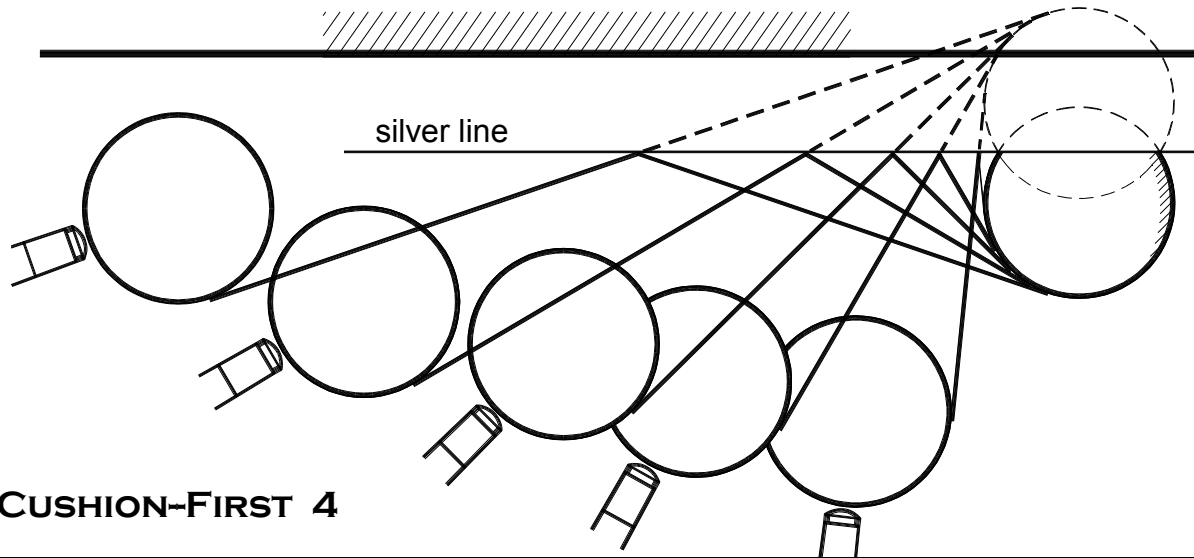
BILLIARDS THE STROKES OF THE GAME PART 1 1912

..... A fact that is quite unknown to the ordinary player, and even to many good players, is that a cushion may impart side to a cue ball or an object ball. On tables with very fast cushions made of soft, yielding rubber, the amount of side which under certain circumstances may be communicated to a ball by a cushion is often very noticeable indeed ; especially is this so if the cushions have a very sharp nose.

..... Nowadays all good tables, instead of being fitted with **moulded** rubber cushions (which sooner or later get very **hard**) are fitted with cushions built up of **strips** of very **yielding** rubber, and on all such tables the **eccentric** angle at which a very fast ball rebounds after striking a cushion at no great angle, has to be reckoned with.

..... In certain positions, this fast-ball eccentric angle is of the greatest **assistance** in keeping a ball out of baulk when playing an in-off. In fact, it is not too much to say that many a stroke which, played on a table with hard cushions, sends the object ball into baulk to remain there, would, if played in exactly the same way in a table with very yielding cushions, not only not send the objectball into baulk, but actually keep it in the upper half of the table.

UZING THE MIRROR IMAGE



In Cushion-First 1 & 2 & 3 we looked at aiming points when the yellow woz frozen on the cushion. In Cushion-First 4 the yellow iz off the cushion ($\frac{1}{4}$ ball).

GEOMETRY If the cushion rebound-angle iz the same az the attack-angle uken uze geometry to judge the aim. And, if it *iznt*, uken uze geometry to help to judge the aim anyhow.

MIRROR Imagin a mirror standing with the *silver-line* of the mirror *parallel* to the cushion & passing throo points that match the *center* of the *qball* frozen on the cushion.

DEAD CENTER Now, if u want to hit the yellow dead-center (cushion-first), just *aim* for the center of the *imaginary* mirror-image of yellow. Right?? Well -- Yes & No Koz u *karnt* hit the dead-center of the yellow *unless* the real yellow givz u a *clear path* to the dead-center of the imaginary yellow. But i am getting off the track.

GRAZE If we want to say graze the *real* yellow, we aim to graze the *imaginary* yellow. Then, we *re-aim* to allow for reality, ie that rebound duznt equal attack. Simple.

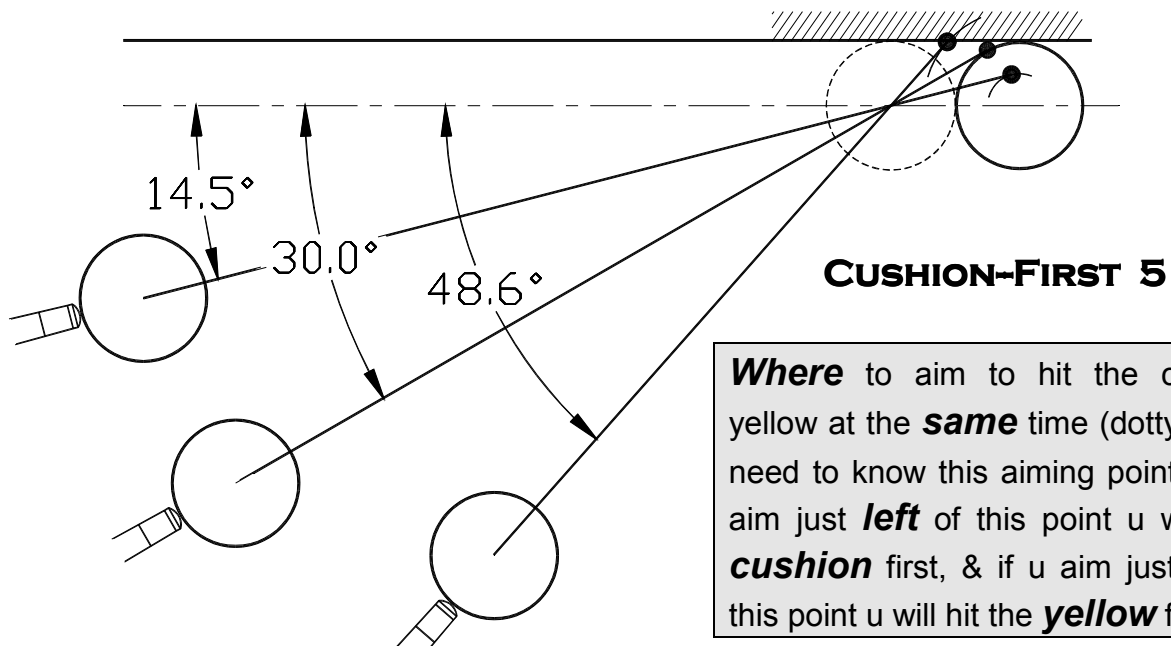
LONG DISTANCE I uze this mirror technique to help me for long distance strokes, such az cushion-first *loozerz* & cushion-first *cannonz* from the Dee.

CLOSE CANNONZ But it duznt help me much in close-cannonz, u are much *better* off just uzing *feel*, forget the mirror. I don't know why i even bothered mentioning it.

CUSHION LINE This remindz me. The cushion-line in my drawingz iz not the cushion face. Koz when the real ball sits against the real cushion it sits partly *under* it, & so the back of the ball iz actually *1mm behind* the *face*. But in my drawingz the *cushion-line* iz always the *effectiv cushion* so to speak, ie *1mm* behind the *actual face* of cushion.

SLIDE The *qball* slidez along the cushion befor rebounding. Soft nursery *cannonz* might *suffer 3mm* of slide along the cushion. That's a lot. Perhaps i should *redraw* the *qball* trajectoryz to show the *penetration* into the cushion & the *slide* along the cushion. But then i would havta firstly *recalculate (inkreec)* my mezured rebound-anglz, so i would be back where i started. Hmmm. I think i will leev thingz az they are for now.

CUSHION-FIRST AIMING POINTS



Where to aim to hit the cushion & yellow at the **same** time (dotty ball). U need to know this aiming point, coz, if u aim just **left** of this point u will hit the **cushion** first, & if u aim just **right** of this point u will hit the **yellow** first.

AIMING POINT This aiming point(s) iz difficult to judge. The drawing showz **3 aiming points** on yellow that might help u.

- 30°** If the qball layz on a 30 degree angle from the correct point on the cushion, u havta aim **half-ball** on yellow to hit the yellow & cushion at the **same** time.
- 15°** If the angle iz 15 degreez, u havta aim three-quarter-ball.
- 49°** If the angle iz 49 degreez u havta aim quarter-ball.

If u are like me u will hav a good idea of where these **3** aiming points on the yellow are -- **quarter-ball, half-ball, & three-quarter-ball** -- koz these are my 3 main aiming points. I uze them for allmost every shot, to help to judge the contact etc for all of my loozertz, winnerz, & cannonz etc. The other **2** aiming points that we all uze are -- **full ball, & zero ball** (ie a thin graze).

2 WRONGZ If your idea of where the points are iz **wrongish** it **duznt** matter. Koz the main thing iz that u praktis the shot, to hit ball & cushion at the same time, uzing your own **silly** verzion of the aiming points, & memorize your own **silly** verzion of the anglez. Koz this iz one case where **two wrongz** ken **make a right**.

TOUCHING BALLZ To help learn the aiming-points, why not put the qball next to the yellow (ie put it where the dotty ball iz drawn). Then get **down** az if u were playing a shot & moov your **head** around to varyus anglz & aimz, especially the 3 mentioned. This will show u the kontakt for every angl from 00° to 90°.

PHANTOM BALL It might even help, during play, to vizualize the abov **phantom** ball **touching** the **yellow**.

POT YELLOW If u do hit the ball & cushion at the same time, u **won't pot** the **yellow**. Not in English billiardz. U havta aim **finer**, sometimez a **lot finer**, especially on a **slippery** cushion, especially for a **hard** hit. This iz koz of **ball-to-ball friction**, which tryz to **throw** the yellow in the direction of the friction force.

REBOUND COMPUTER PROGRAM

Billiardz Arithmetically Treated looks into rebound-anglz in detail. And, it includez a computer program for ball rebound from a cushion.

This program calculates (a) the rebound-angl, (b) speedz & (c) spinz during any time during the impakt event. Allso it calculates (d) the total impakt time, & (e) the penetration into the cushion, at any time. Some strange stuff happenz.

In addition, it calculates (f) the ball'z final trajectory, ie after table-skidding haz stopped, ie when the ball iz rolling happyly, plus (g) the final speed, & (h) the final spin.

The program calculates the energy lossez due to (i) cushion bending, (j) ball-to-cushion skidding, (k) ball-to-bed skidding, & (l) jumping.

The program needz to know (1) the cushion hight & (2) the cushion rezillience, & (3) the ball-to-cushion friktion, & (4) the ball-to-bed friktion. Don't know theze -- DuzzenMadder.

It needzta know (A) the ball size & (B) the mass, & (C) the initial speed, (D) angl, (E) spin & (F) topspin (or screw).

The program also drawz (m) the ball trajectory inside the cushion (ie the slide). This givz an indication of how far a *q*ball might need to hit a cushion in advance of a frozen ball, when u wish to pot the ball.

TRIALZ TESTS & EXPERIMENTS

But uken work out how far in advance u havta hit the frozen red to pot it along the cushion. Firstly, uken just play the stroke over & over trying different aimz.

But what i hav in mind iz that u place the yellow on the cushion say **5mm** in advance of the red & hit the yellow full-ball, from any *q*ball pozzzy in question. U will soon find the gap that givz the best rezult. This needed gap will inkreec with strength. I hav found it to be over **10mm** at timez.

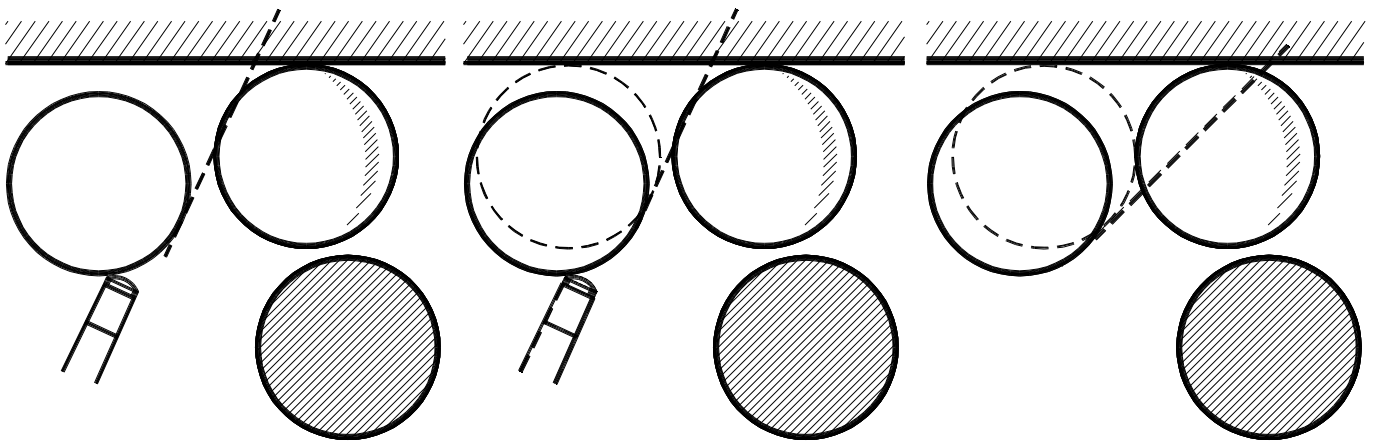
RUNNING SIDE

Regarding this pot along the cushion, **Joe Davis** sed that a little **running-side** on the *q*ball helps the pot. The running-side inkreecez the slide distance, & reducez the throw of the impakt. The throw would uzually take the frozen ball away from the cushion, with zero throw the ball might hug the cushion all the way to the pocket. Some playerz say that the running-side helps koz the tranzmitted side makes the pocket larger, but this iz overstating the case.

STRIPED POOL BALL

Uken test this sort of stuff by uzing a striped pool ball. Lay it against the cushion with the stripe parallel to the cushion. See what happenz to the orientation of the stripe when u (a) pot it without uzing any spin, (b) pot it by hitting a frozen ball 5mm or 10mm from the pool ball, (c) pot it uzing a little running-side, (d) pot it uzing a lot of running-side, (e) pot it uzing wrong side. Some very weird thingz happen, or don't happen. Hmmmmmm.

DIZZY'Z GREAT ADVENTURE



CUSHION-FIRST 6A

CUSHION-FIRST 6B

CUSHION-FIRST 6C

Here, koz the **red** iz a little too far **east** for comfort, the **cushion-first** cannon iz **not** eezy. But the **juicy** yellow-first cannon with right-hand-side iz a **trap**.

Let's watch Dizzy to see what she duz.

6A **Dizzy** takes the bait, & decidez to play the thin yellow-first cannon, az shown. She aimz **very** thin on yellow so that it **duznt** go too far **east**. But, u should see her **face** when the qball hits the **cushion first**, then hits the yellow **thickish**, & **missez** the red by a **mile**. What happened ??

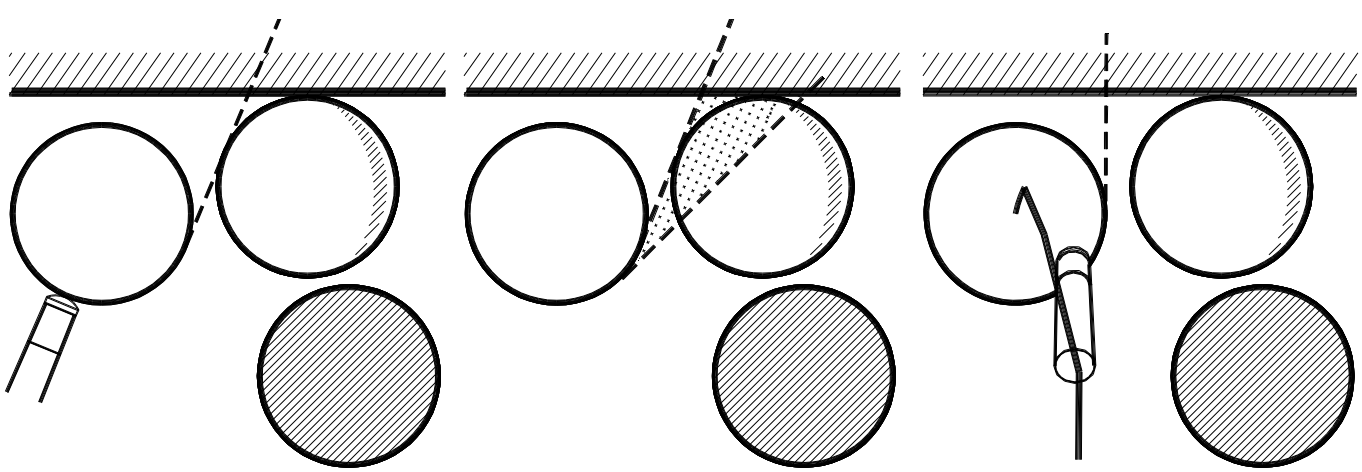
6B Here the **broken ball** showz where Dizzy'z qball **hit** the cushion. A hell of a long way **before** the yellow. She would hav gotten the cushion-first even if she aimed a little thicker.

And the **right-hand-side** rezulted in the qball hitting the yellow **thickish**. And then it **missez** the **red**. It might hav missed even with **zero** side.

6C Here the **broken ball** showz the aim **needed** to hit the yellow & cushion at the **same** time. This aiming point iz **thicker** than a **quarter-ball**.

So, if Dizzy aimed a little **thicker** than this, a little thicker than $\frac{1}{4}$ ball, to get her **yellow-first** cannon, the yellow would hav gone a **loooong** way east. Dizzy would hav gotten her cannon, **but** the **leev** would hav been **bad**.

So, in this pozy, a **yellow-first** cannon iz **hopeless**. (continued)



CUSHION-FIRST 6D

CUSHION-FIRST 6E

CUSHION-FIRST 6F

6D As mentioned much earlier, when the yellow is **frozen**, if u aim to **graze** the left-hand-side of the yellow (as shown) the **qball** will hit the **cushion-first** & then it will **graze** the right-hand-side of the yellow (not shown). At least it duz if the rebound-angle **equalz** the attack angle.

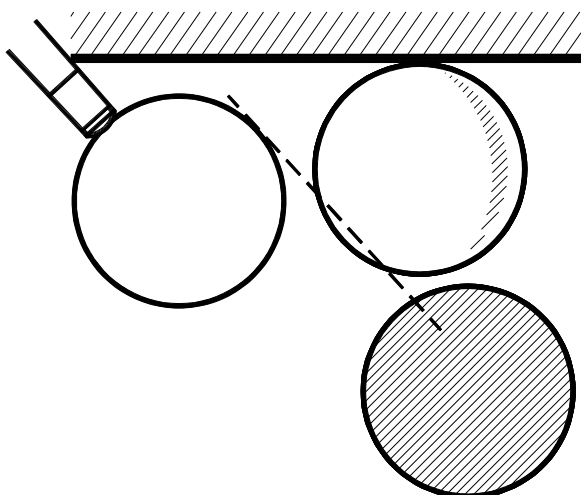
Dizzy obviously duznt know about this handy little **Mirror-Image Rule**.

6E This showz the **no-woman'z-land**. If Dizzy aimz **inside** this zone (or anywhere **left** of this zone), she will hit **cushion-first**.

As ken be seen, there iz about **25°** of no-woman'z-land, where **ucan't** score a **cushion-first-cannon** in this particular arrangement of the ballz. It's **hard** to **believe** with the ballz so close & **inviting**. But don't tell Dizzy. She owe'z u beer.

Moov the **qball** a little **right** (not shown) & the no-woman'z-land **shrinks** very quickly. Moov the qball to the **left** (not shown) & the no-woman'z-land **shrinks** quickly az well, for scoring. But, the no-womanz-land for a score **plus** a good leev iz always **larger** than the no-womanz-land for just the score.

6F As not shown, it **might** be possible to get the cushion-first cannon by **aiming** further **left**, & uzing right-hand-side. Here in 6F we show a shot with **swerv** (& side), aiming perhaps **square** to the cushion. This certainly obviates the **missed** cannon. But it iz **not** an eezy shot when the **qball** iz this **close** to the cushion, u might **foul**. **Chalk-up**. And mind the **foul**.



CUSHION-FIRST 6G

But, what's the big deal ???

Dizzy should hav played the direct **thin-thin** cannon, az shown. It's a perfikt ThinAlong.

Anyhow, it looks like Dizzy'z glass iz empty again.