Another 2.007 PS4/PS5-style Sample Calculation

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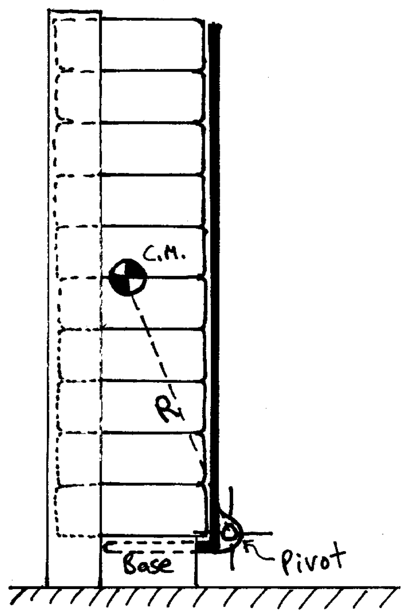
3/4/99

Collecting 10 additional pucks

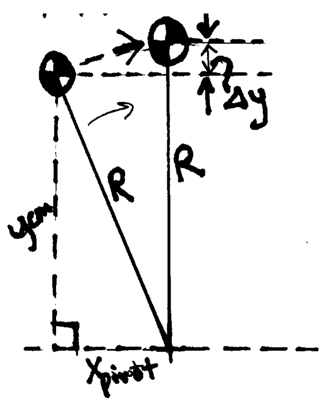
Basic feasibility analysis:

How much work is required to collect the stack of pucks?

- Assume puck collecting module is a tilting forklift:



This collection method requires a small increase in height of the pucks:



which requires a certian amount of energy. Thinking ahead to possible DP's that can execute the FR of collecting pucks, we can compare the amount of Energy required to the Work done by a 2.007 piston in one stroke.

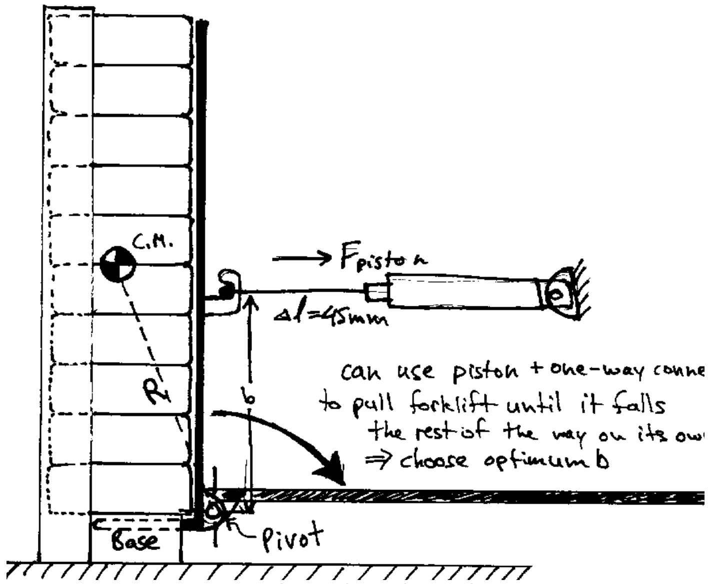
is DeltaPE of pucks < max piston work (one stroke)?

Inputs		
Mass of puck	**0.165**	**kg**
#pucks	**10**	
x_pivot	**1.75**	**in --horiz. Dist to pivot form puck cm**
Ycm	**5**	**in-- vert dist to puck stack c.m.**
g	**9.8**	
Piston Force	**27**	**(N) (pull)**
Piston Stroke	**0.045**	**m**
Max Piston Work	1.215	J -- one stroke
DeltaY	0.297405	in
DeltaY	0.0075541	m
DeltaPE	0.1221496	

Ratio of work avail to delta PE	9.94682	must be > 1

So, it is VERY possible--

Now that we know that a single piston can do the job, a specific method can be designed.
This specific method will need to be checked to verify that at all times there is enough force in the piston.
One possible way to harness a single cyclinder for this task is sketched below. The piston pulls horizontally at some height b, and when the stack of pucks crosses a critical point, it falls the rest of the way under the effect of gravity. It is straightforward to find the minimum value of b required to have enough force, and the maximum value of b to have enough piston stroke.



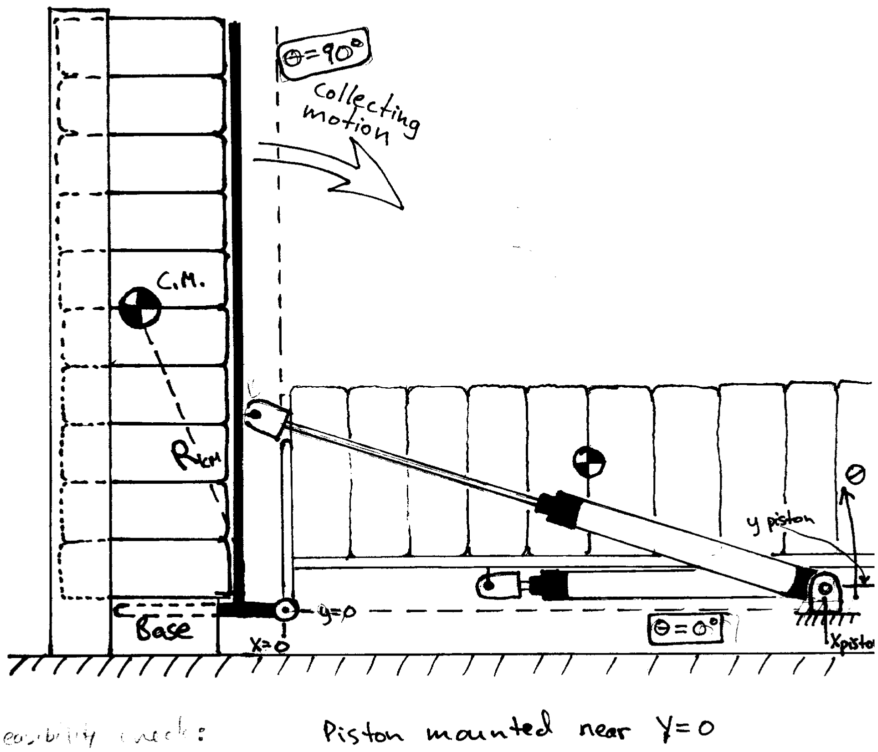
This method may be undesirable because of the free fall of the pucks.

Is there a method with greater control over the puck collector’s motion?

FR: motion should be calm and under control

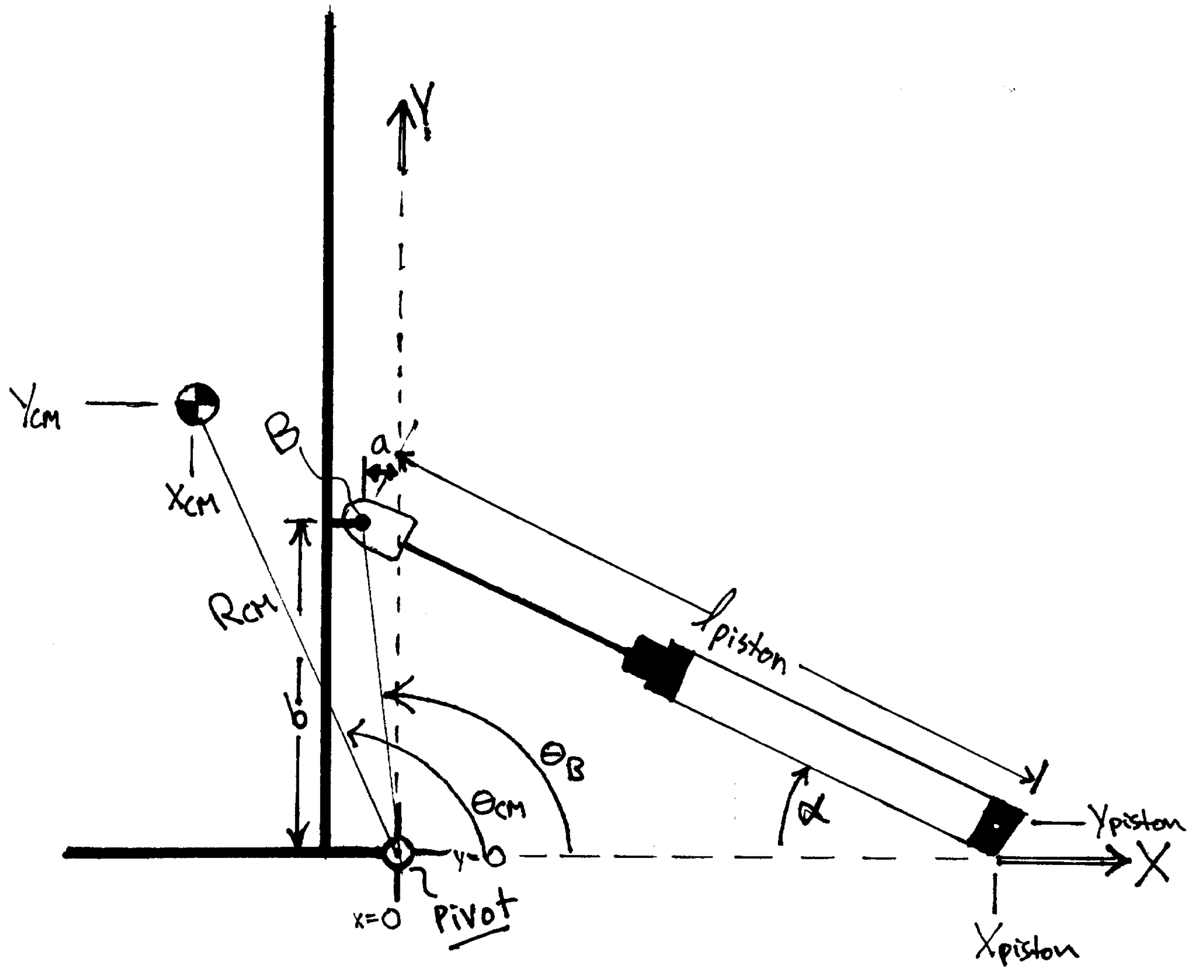
--> Keep piston connected at all times-- flow controls can be used to control fall of pucks.

One possibility:



Is this the best way to do it?

Make general geometry/physics model and use spreadsheet to optimize



*Theta is defined as the (CCW) angle of the long edge of the puck collecting forklift from the horizontal.

The equations that define the model for the geometry (kinematics):

X_{cm_o} – original X-coordinate of Center of Mass of Pucks ~ −2"

Y_{cm_o} " Y-coord. ... $Y_{cm_o} \approx 5"$ $X_{cm_o} = -50.4\text{ mm}$

$$R_{cm} = \sqrt{y_{cm_o}^2 + x_{cm_o}^2}$$

puck collector angle θ:

$$\theta(t=0) = 90^\circ$$
$$\theta(t_f) = 0^\circ$$

$$\theta_{ocm} = \tan^{-1}\left(\frac{X_{cm_o}}{Y_{cm_o}}\right)$$

$$\theta_{cm} = \theta + \theta_{ocm}$$

a – original x-coord. of piston attach point } wrt pivot point
b – " y-coord. " " " "

$$R_B = \sqrt{a^2 + b^2}$$

$$\Theta_{oB} = \tan^{-1}\left(\frac{a}{b}\right)$$

$$\Theta_B = \theta + \Theta_{oB}$$

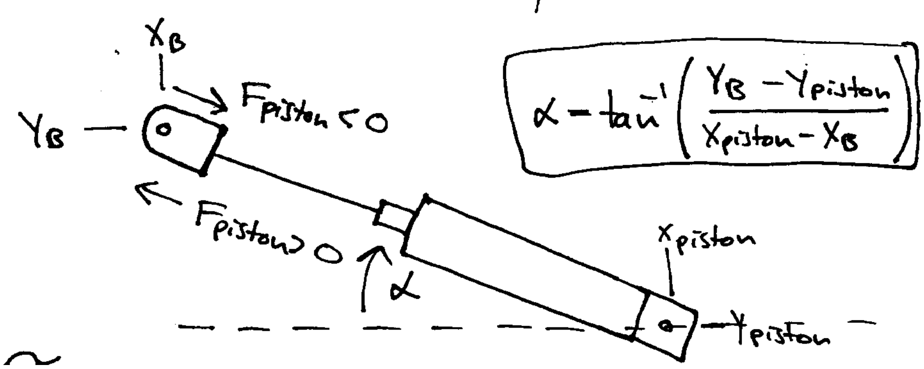
$$X_B(\theta) = R_B \cos \Theta_B$$

$$Y_B(\theta) = R_B \sin \Theta_B$$

$$X_{CM}(\theta) = R_{CM} \cos \Theta_{CM}$$

$$Y_{CM}(\theta) = R_{CM} \sin \Theta_{CM}$$

Piston Forces + Geometry



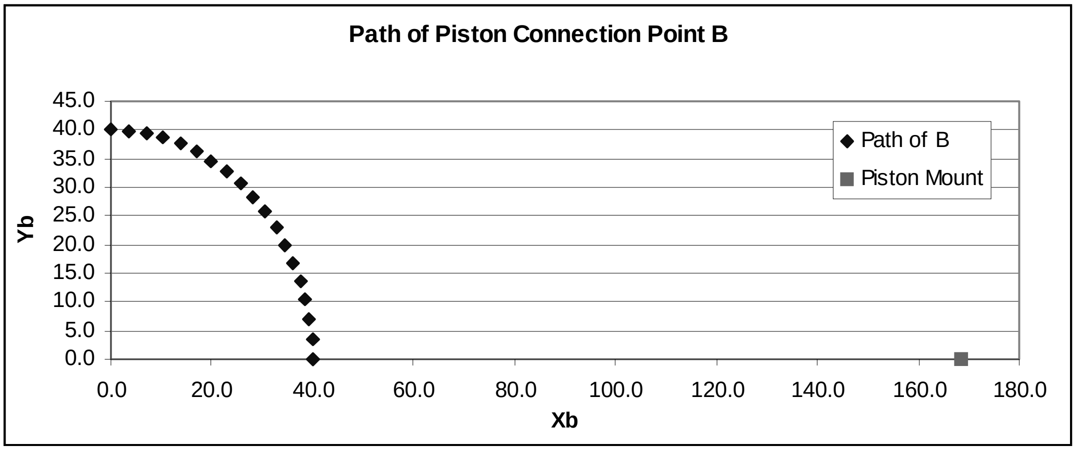
$$\alpha = \tan^{-1}\left(\frac{Y_B - Y_{piston}}{X_{piston} - X_B}\right)$$

So the relations are entered into a spreadsheet...

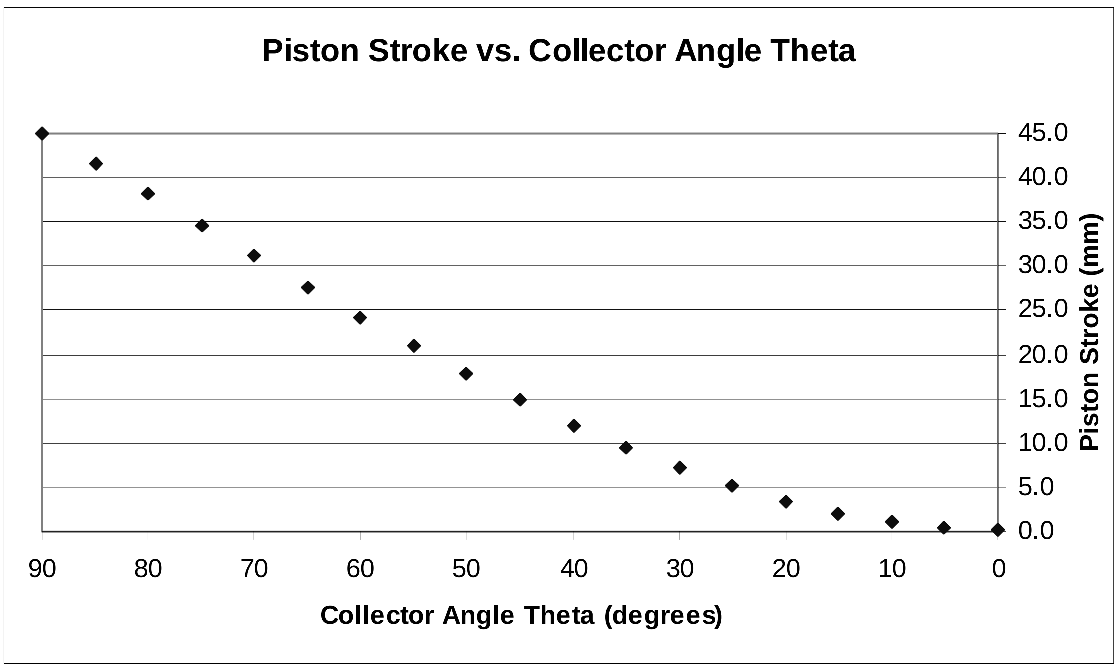
:

Collecting 10 pucks using a tilting forklift									
INPUTS	***value***	***units***		***coordinate system: pivot point is (0,0)***					
constants						y is + vertical up			
weight of 10 pucks	1.65	kg				x is + horizontal right			
g	9.8	m/s^2							
Piston Force @60p	27.1	N							
Lpiston ext	173	mm	extended length between mtg hole and clevis hole (~173 or ~65)						
stroke	45	mm							
~constants									
Xcmo	50.8	mm	Initial Horizontal distance from pivot to Center of Mass of pucks						
Ycmo	134	mm	Initial Vertical distance from pivot to Center of Mass of pucks						
minor parameters									
a	0	mm	X-position of piston connect point B (note if B to left of pivot, a<0)						
Theta	not here, but in series below. Defines motion of puck collector								
pressure	60	psi							
key variables:									
b	40	mm	vert. Distance from pivot to piston connect point B						
Ypiston	0	mm	height of piston mount relative to pivot						
Intermediate stuff									
Xpiston	168.312	mm	Driven by location of B; Ypiston; at theta=90, piston @full extensi						
Piston Force	27.1	N	at	60	psi				
Lpiston min	128	mm							
ThetaCMo	0.36236	rads	20.7619	degrees					
rCM	143.306	mm							
ThetaBo	0	rads	0	degrees					
rB (m)	40	mm							

We can use some simple results to check the validity of the model:



This shows that, indeed, the point B is rotating about the pivot point (0,0)
What effect does the motion of the piston attachment point B have on the piston?



Just the geometry is not enough to check-- Does the piston have enough force when needed?

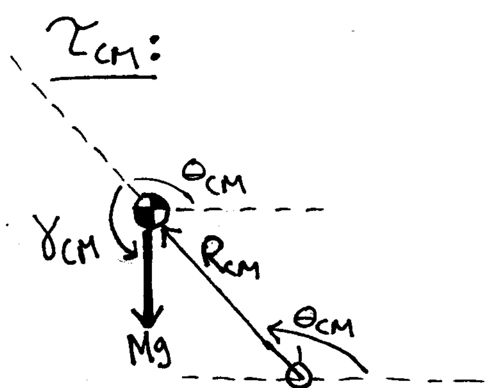
Torque balance:

$$\sum \vec{\tau} = 0$$

$$\Rightarrow \tau_{CM} = -\tau_{piston} \quad \text{(watch sign convention)}$$

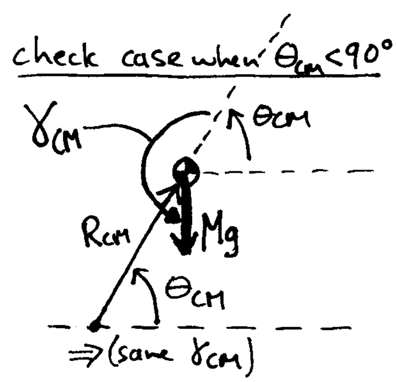
$$\vec{\tau} = \vec{r} \times \vec{F} = r \cdot F \cdot \sin\gamma$$

The Torque about the pivot point due to the pucks is:



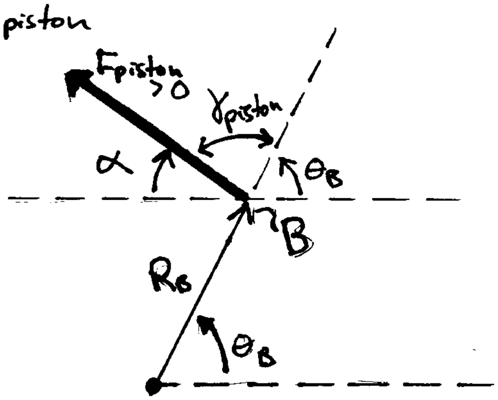
$$\boxed{\gamma_{CM} = 270° - \theta_{CM}}$$

$$\boxed{\tau_{CM} = Mg\, R_{CM} \sin\gamma_{CM}}$$



The Torque about the pivot point due to the Piston is:

τ_{piston}



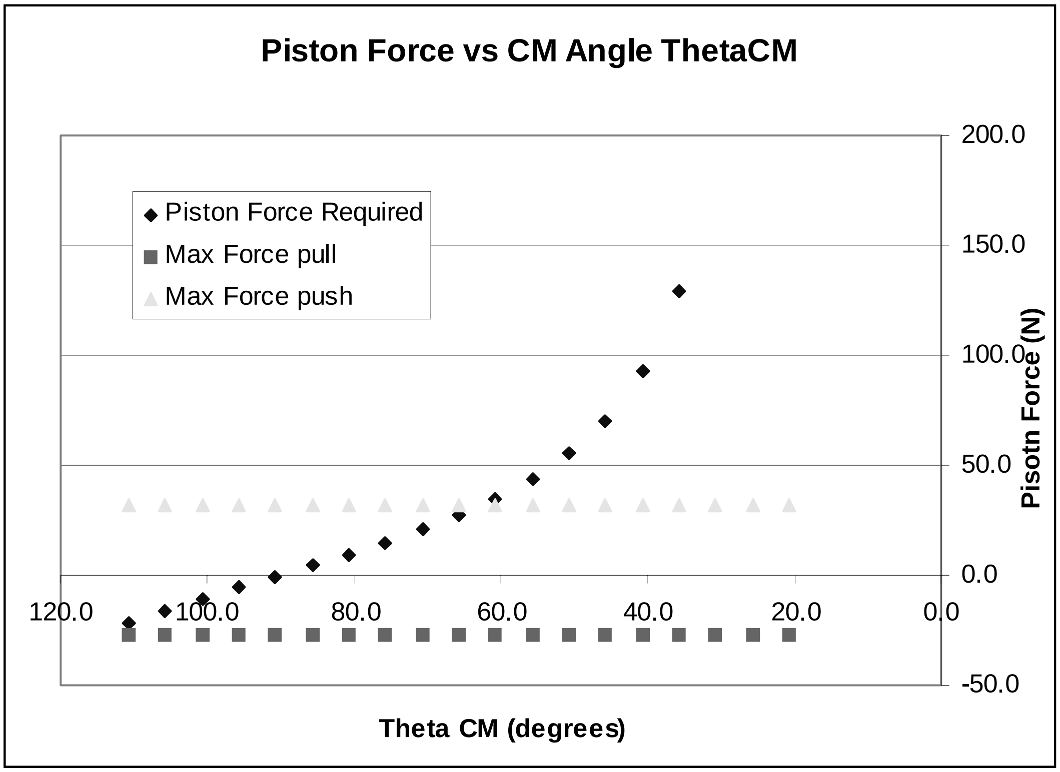
$$\gamma_{piston} = 180° - \theta_B - \alpha$$

$$\tau_{piston} = R_B \cdot F_{piston} \cdot \sin \gamma_{piston}$$

since $\tau_{piston} = -\tau_{CM}$

$$\Rightarrow F_{piston} = \frac{-\tau_{CM}}{R_B \sin \gamma_{piston}}$$

for piston at Ypiston = 0:



The piston just barely has enough force to start the pucks tipping, then the force on the piston becomes quite large as the collector settles to horizontal.

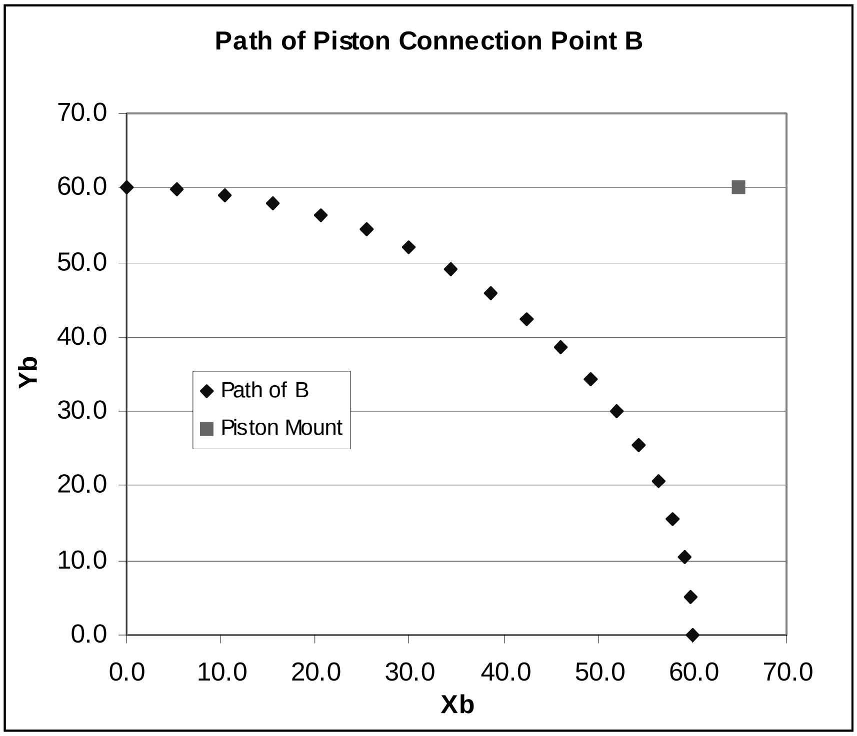
Is there a different arrangment that allows for a "softer" landing?

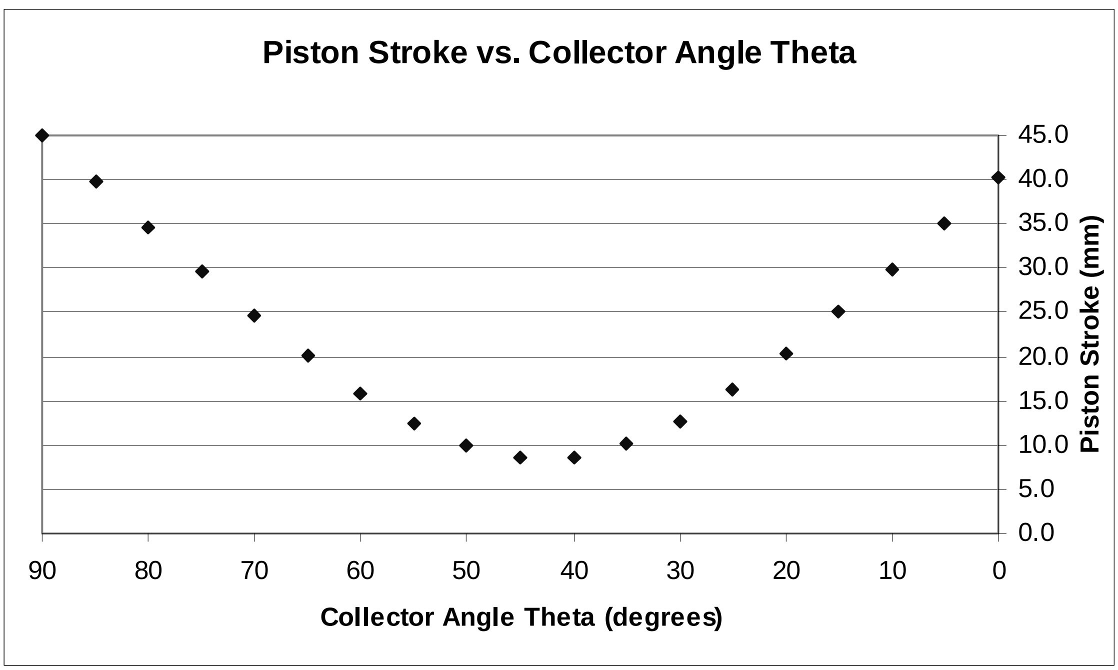
Tweaking the parameters b and Ypiston, we find a piston placement such that the piston is pulling directly to the right at the beginning, and directly up at the end of the collection motion:
Note that for this option, the piston is pivoted at the "nose," And it may be necessary to position

Lpiston ext	65	mm	extended length between mounting hole and clevis hole (.173) (.0

key variables:			
b	60	mm	vert. Distance from pivot to piston connect point B
Ypiston	60	mm	height of piston mount relative to pivot

the piston off-center to allow the pucks to fall past its mounting point.


Path of Piston Connection Point B
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Yb
Path of B
Piston Mount
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Xb


Piston Stroke vs. Collector Angle Theta
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Piston Stroke (mm)
90
80
70
60
50
40
30
20
10
0
Collector Angle Theta (degrees)

Looking at the force with respect to rotation of the puck Center of Mass- once CM past 90 degrees, just need to damp the descent, and the piston almost has enogh force to do so (good enough-- certainly better than the 2 other options considered)