Grand Action:
A Balancing Act

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February 17, 2018

Download class handout from:
www.pianosinsideout.com/Classes

The Touch Journey

- Intro to static balancing (today)
- Practical Touch
  (Non-invasive analysis and free calculator: http://pianosinsideout.com/Bonus.html)
- *Pianos Inside Out* action geometry chapter
- David Stanwood's Precision Touch Design
  (Method: https://www.stanwoodpiano.com
  Measurement kit: Pianotek Supply part #D-29
  Coming soon: Stanwood Dynamic Playing Table of Elements)
- Fandrich-Rhodes
  (Inertial Touch Force concept,
  Weight Bench kit and software: http://fandrich.com)
- Rick Voit (Key Force One, on-going research, PTJ articles)
- Yuji Nakamura (simplified analysis methods, PTJ articles)
- Nick Gravagne (Action Geometry Program: http://www.gravagne.com/)

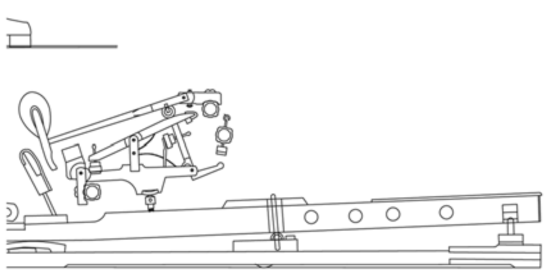
Agenda

- Action as a lever
- Action forces
  … and how they feel
- Measuring DW down weight and UW up weight
- Calculating BW balance weight and F friction
- Advantages of BW balance weight
- How to rebalance action,
  limits of balancing
- What are we measuring?

Action as a Lever

What is the piano action?

- A set of levers that transfers force from the finger to the hammer:



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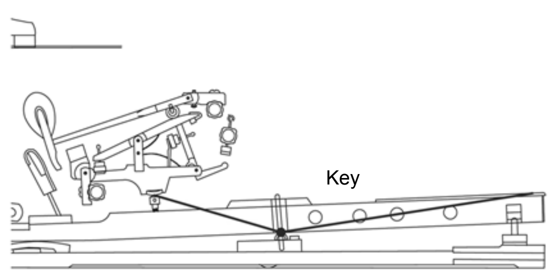

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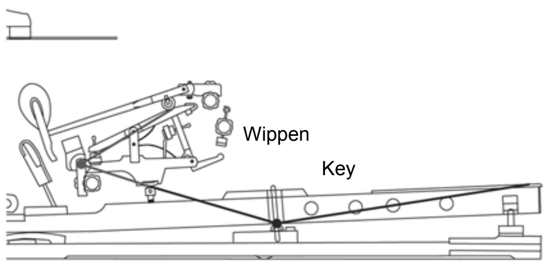

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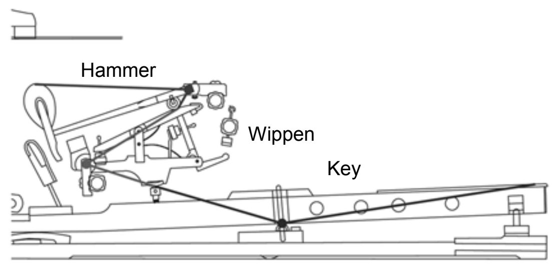
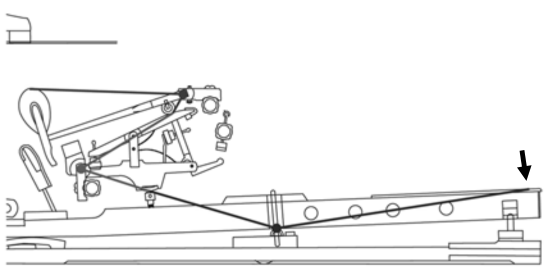


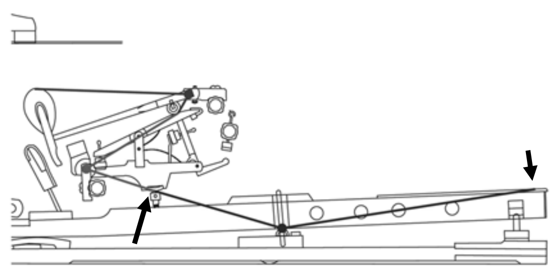
How do the levers work?

- Applying force to the key:



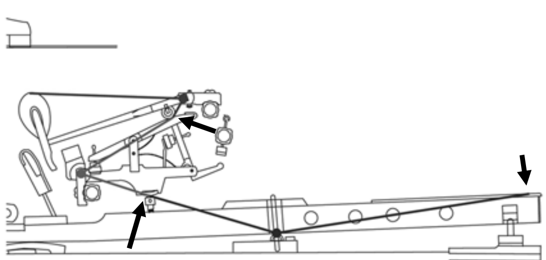
How do the levers work?

lifts the wippen:



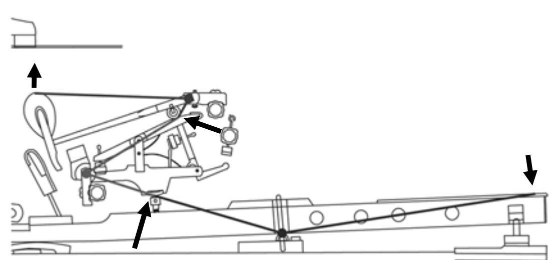
How do the levers work?

which pushes the shank up:



How do the levers work?

and lifts the hammer:



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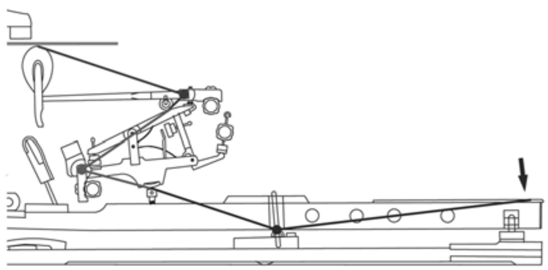

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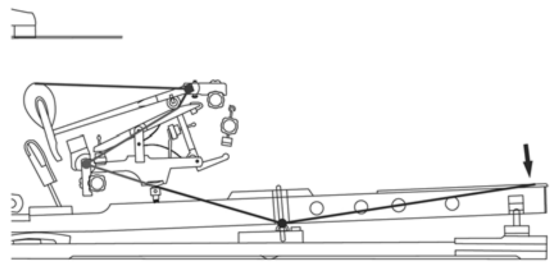
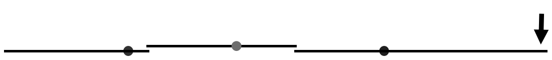


How do the levers work?

The angle of each lever doesn’t matter.
The action could be laid out like this:



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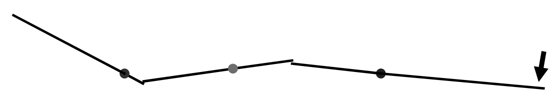
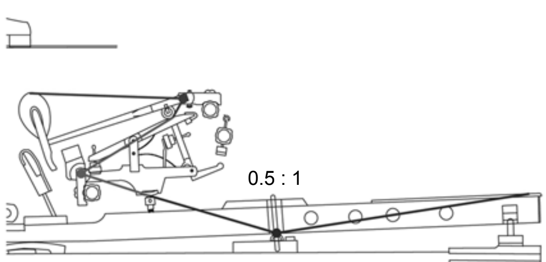


How do the levers work?

- The levers have different ratios, which can be measured geometrically:



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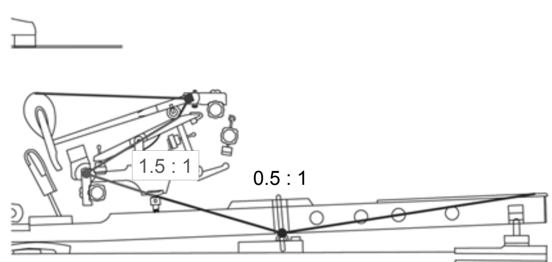

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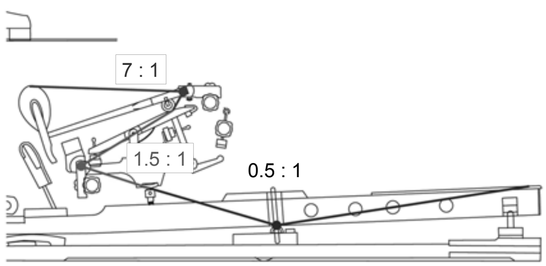
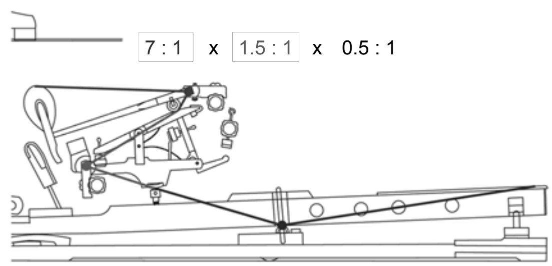


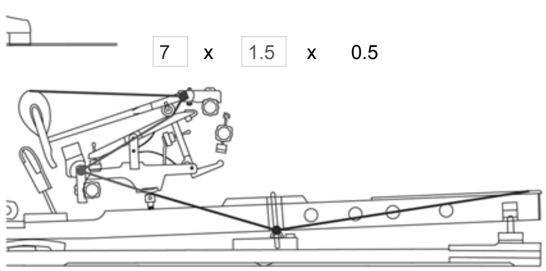
How do the levers work?

- By combining them:



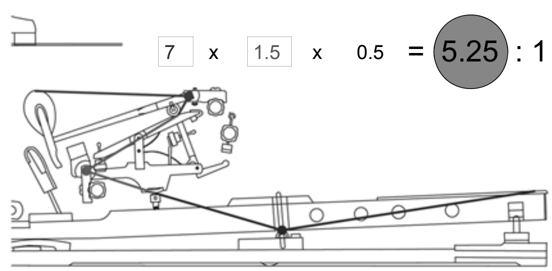
How do the levers work?

and reducing:



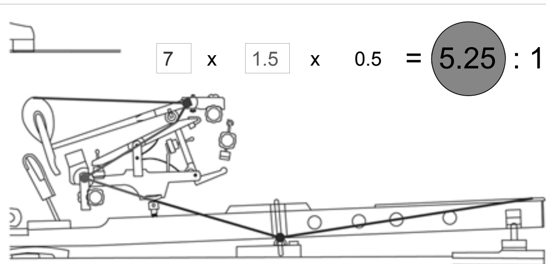
How do the levers work?

we can calculate the total **geometric leverage ratio**:



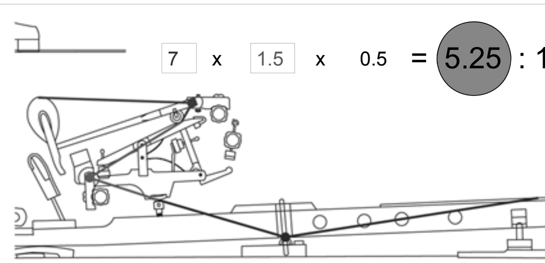
How do the levers work?

which approximates the ratio between **finger force** and **hammer “weight”**, or …



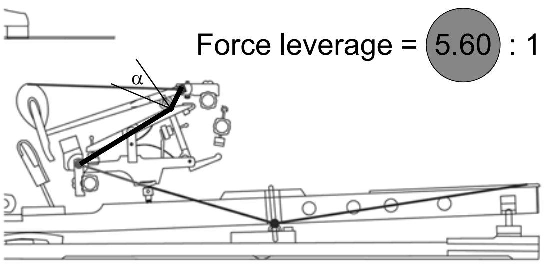
How do the levers work?

force leverage ratio.



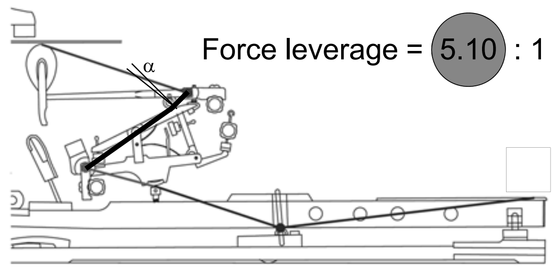
How do the levers work?

Force leverage ratio is higher at rest due to the angle between these two levers:



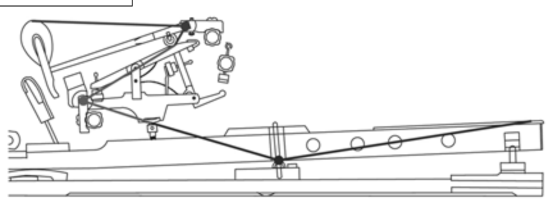
How do the levers work?

… and decreases toward escapement as the angle gets reduced:



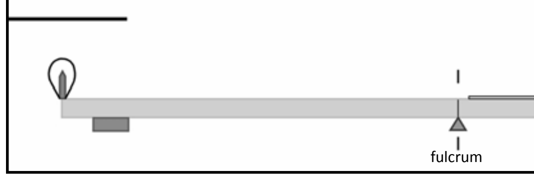
Action as a single lever

- To better visualize the action leverage ratio, let's reduce the action to a see-saw:



Action as a single lever

… or a very long key with the fulcrum (axis of rotation) far off center:



Action as a single lever

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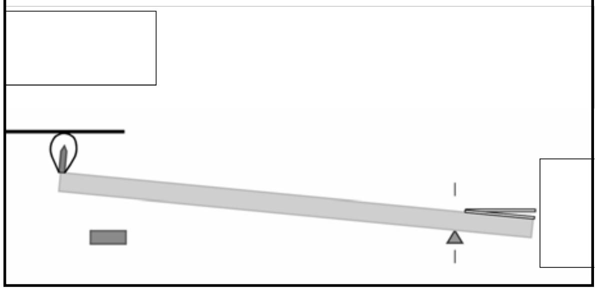

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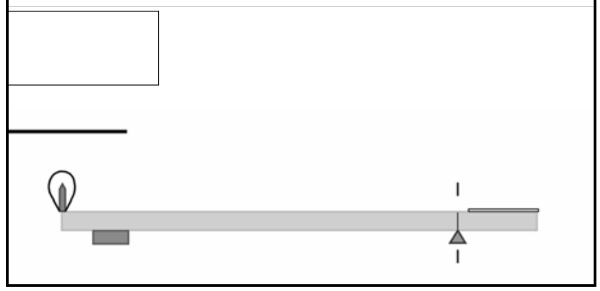
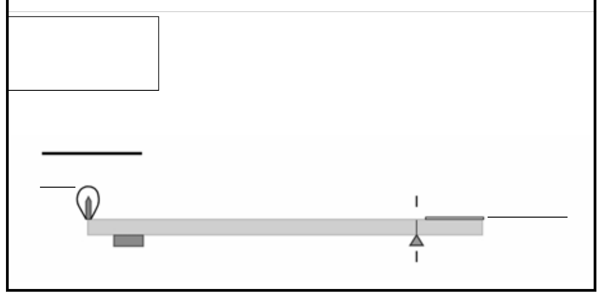


Action as a single lever

By observing the weights and distances on either end:

Action as a single lever

Our extra long key translates:



Action as a single lever

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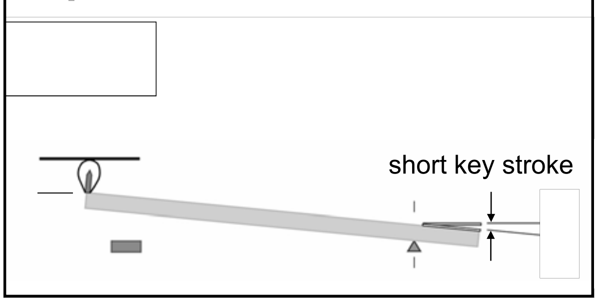

Action as a single lever

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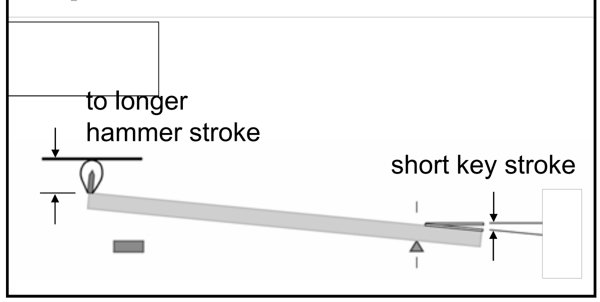


Action as a single lever

Our extra long key translates:

and:

low hammer weight

to greater "play weight"

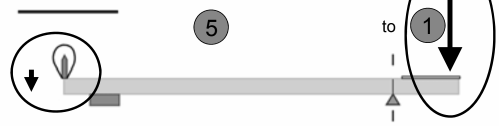
If we know the leverage ratio …

… we can measure one end and calculate the other end

and:

low hammer weight

to greater "play weight"



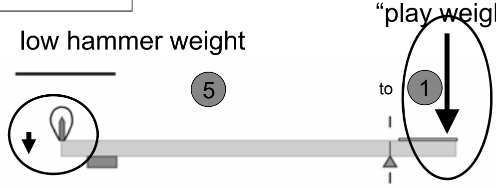
If we know the leverage ratio …

… or vice versa

and:

low hammer weight

to greater "play weight"



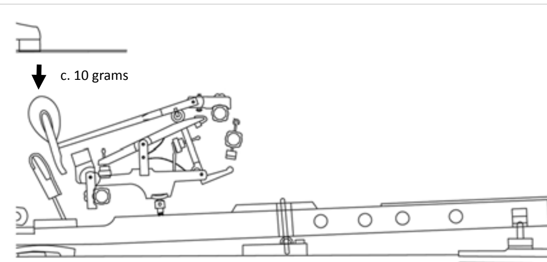
Summary of grand piano leverage

- 3 levers = single lever (seesaw)
- Force leverage (close to escapement) ~ geometric leverage
- Leverage translates:
  - Long blow distance to Short dip
  - Light hammer to Greater "play weight"
- Action leverage allows predicting the force or weight on the other end of the action

Action Forces

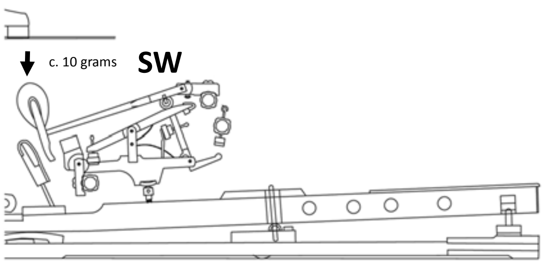
What makes the piano action heavy or light?

- The hammer on one end is pulled down by gravity:



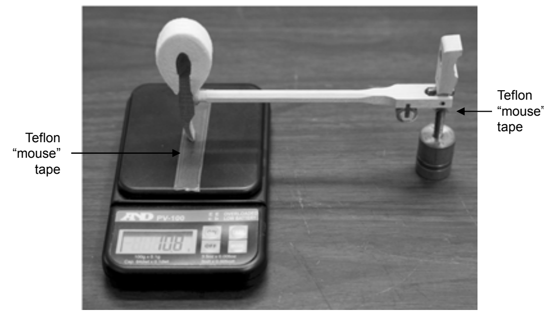
What makes the piano action heavy or light?

- The weight of the hammer and shank is called strike weight (**SW**) :



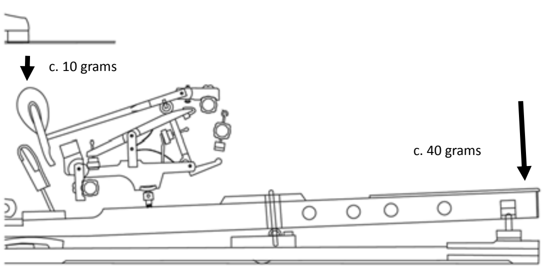
What makes the piano action heavy or light?

Measuring strike weight (**SW**) on a scale



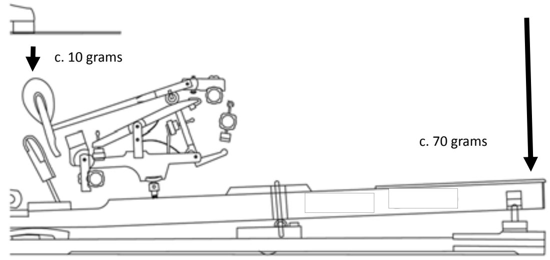
What makes the piano action heavy or light?

- To overcome **SW**, some force is needed to depress the key:



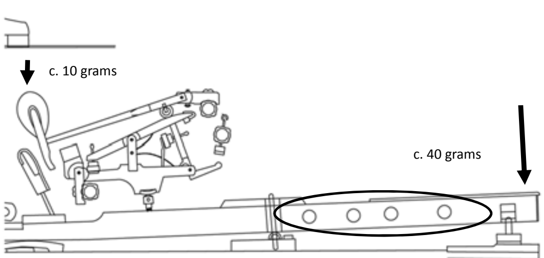
What makes the piano action heavy or light?

- Without leads in keys, the finger force would need to be too great:



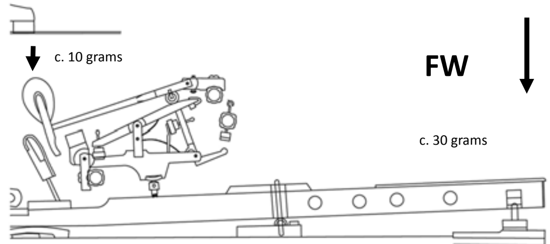
What makes the piano action heavy or light?

- Leads reduce the needed force.



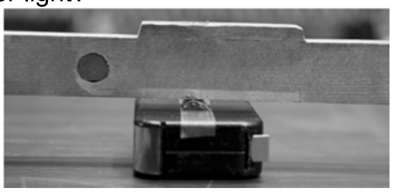
What makes the piano action heavy or light?

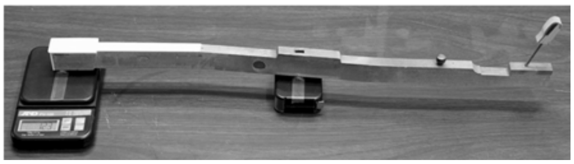
- Leads cause the front of the key to be pulled down by gravity. That is the front weight (**FW**) :



What makes the piano action heavy or light?

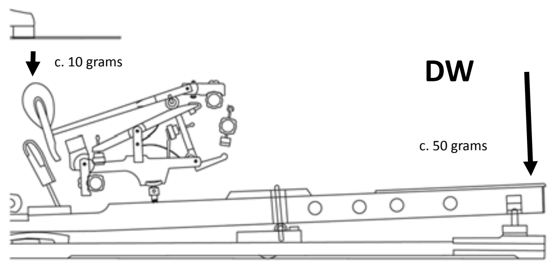
Measuring front weight (**FW**) on a scale





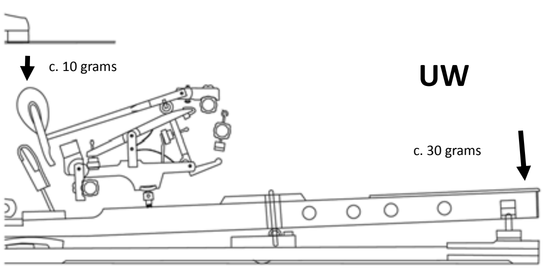
What makes the piano action heavy or light?

- To start depressing the key, the finger applies the downweight force (**DW**):



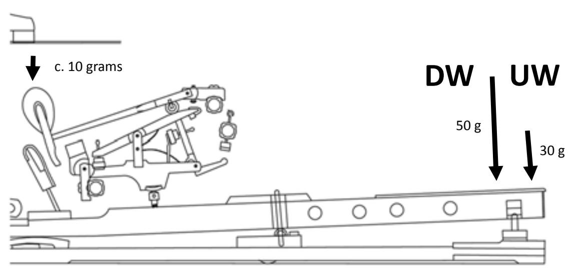
What makes the piano action heavy or light?

- … and to allow the key to return slowly, the finger holds the key with the upweight force (**UW**):



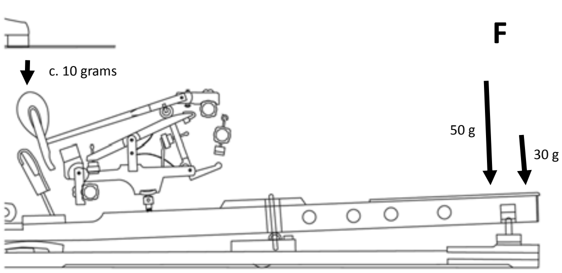
What makes the piano action heavy or light?

- What causes the discrepancy between **DW** and **UW**?



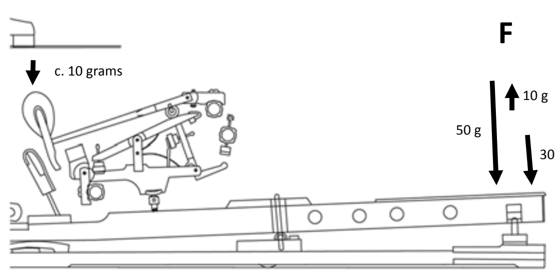
What makes the piano action heavy or light?

- Friction (**F**)!



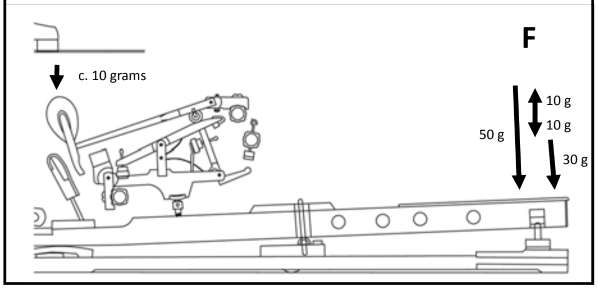
What makes the piano action heavy or light?

- Friction (**F**)! 10 grams during downstroke:



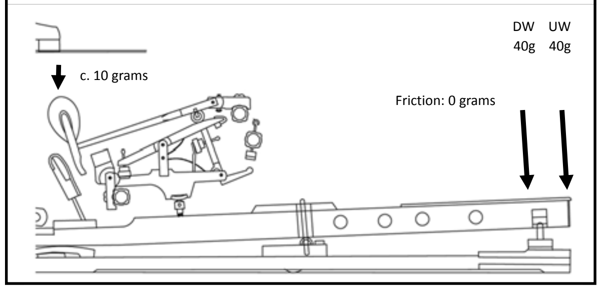
What makes the piano action heavy or light?

- Friction (**F**)! And 10 grams during upstroke:



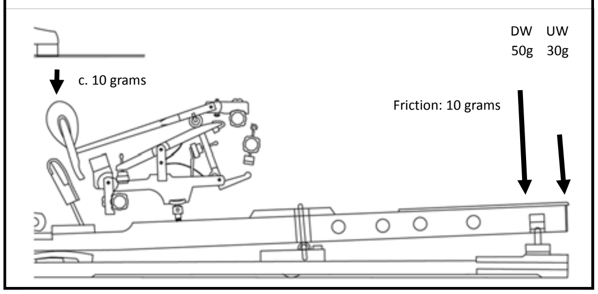
What makes the piano action heavy or light?

- Without friction **DW** and **UW** would be the same:



What makes the piano action heavy or light?

- Friction pushes **DW** and **UW** apart:



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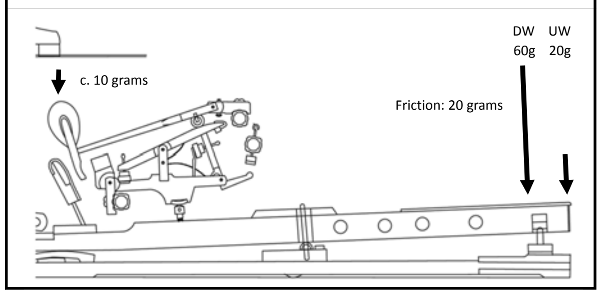
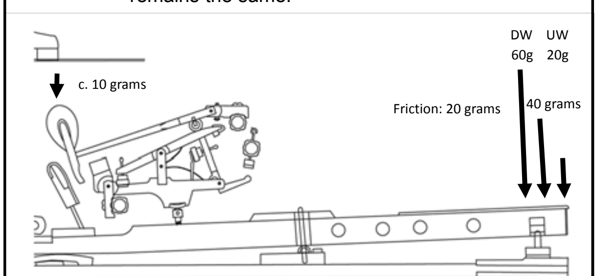


What makes the piano action heavy or light?

- … but the average of **DW** and **UW** remains the same:



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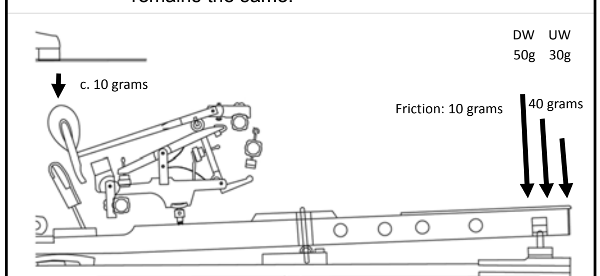

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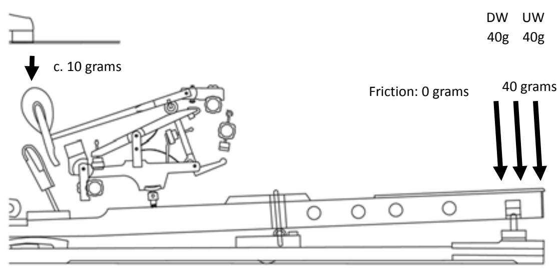
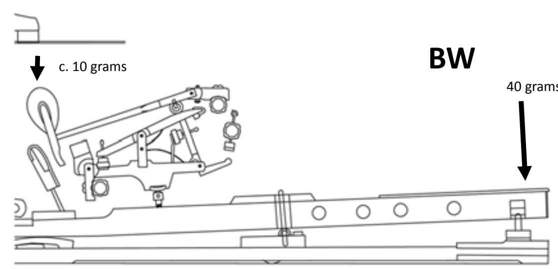


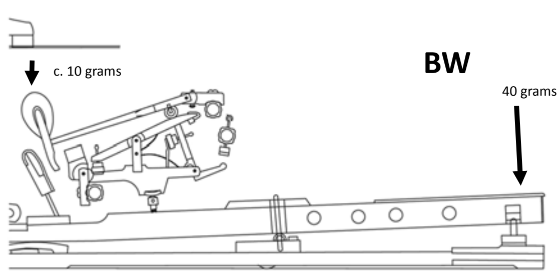
What makes the piano action heavy or light?

- This imaginary force is called balance weight (**BW**).



What makes the piano action heavy or light?

- BW is very useful because it allows you to ignore discrepancies in friction (**F**) during balancing.



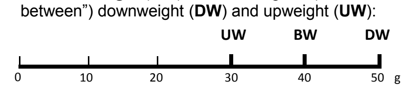
Summary of action forces

- Hammer and shank “radius” weight is strike weight (**SW**)
- The weight of the front of the key is front weight (**FW**)
- Downweight (**DW**)
- Upweight (**UW**)
- Balance weight (**BW**) is avg. of DW and UW
- Friction (**F**) is half of discrepancy between DW and UW
- Friction (**F**) is the discrepancy between BW and DW; BW and UW

Advantages of Working with Balance Weight

Why should we go by balance weight?

- **Balance weight** (**BW**) is the average of (or “value between”) downweight (**DW**) and upweight (**UW**):

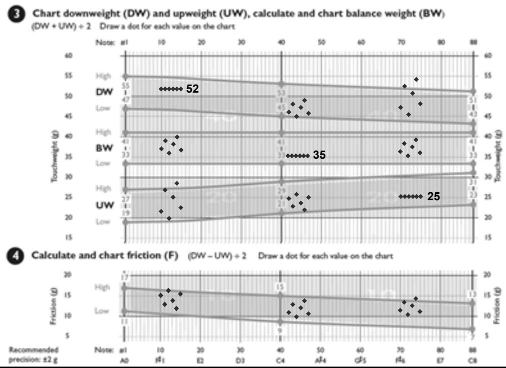


BW = (DW + UW) / 2
BW = (50 g + 30 g) / 2
BW = 80 g / 2
BW = 40 g

In even the best grands, **Friction** varies by 2-4 g note to note.
How does that affect touch if we aim for a smooth:

- DW
- BW
- UW?

Why should we go by balance weight?



Why should we go by balance weight?

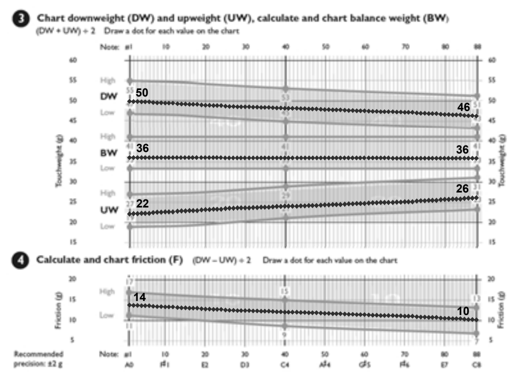
- If DW is consistent, UW varies by **twice as much** as BW
- If UW is consistent, DW varies by **twice as much** as BW
- If BW is consistent, DW and UW vary by **same amount**

Why should we go by balance weight?

- **Friction** (**F**) is half the difference between downweight and upweight:

  F = (DW - UW) / 2

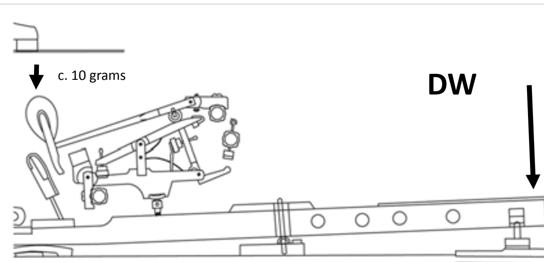
- Even friction = consistent DW, UW



How Do Action Forces Feel?

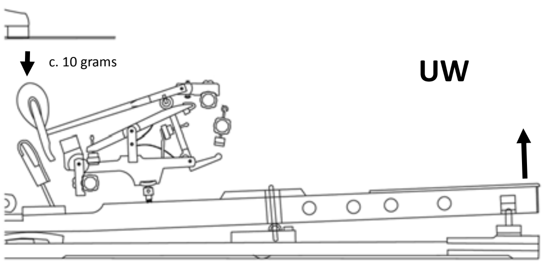
How do action forces feel?

- **DW** feels **resistive**.



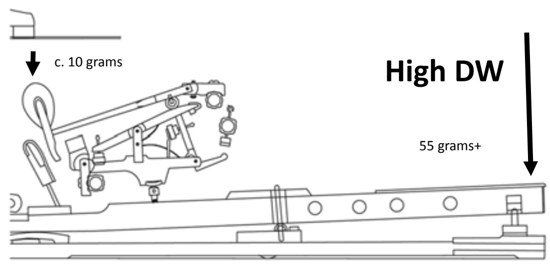
How do action forces feel?

- **UW** feels **repelling**.



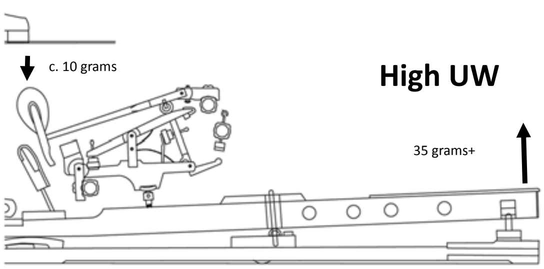
How do action forces feel?

- High **DW slows you down**. It makes you **strain** to play *ppp*, reducing control.



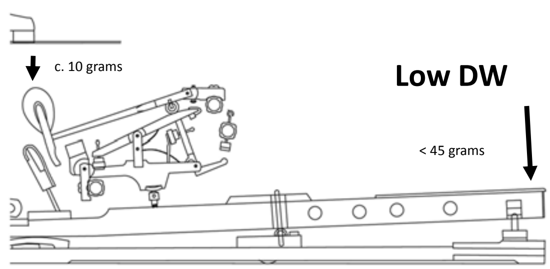
How do action forces feel?

- High **UW speeds up** repetition by pushing the finger up, but this feels uncomfortable.



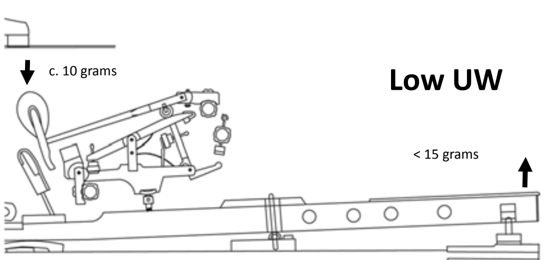
How do action forces feel?

- Low **DW** feels like nothing to bite into. Too little resistance feels flyaway, also reducing control.



How do action forces feel?

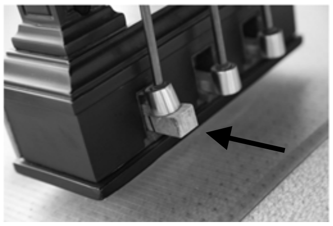
- Low **UW** feels sluggish, as if the action lags behind you. Repetition is impeded. Dancing keys?



Measuring DW and UW

Prepare

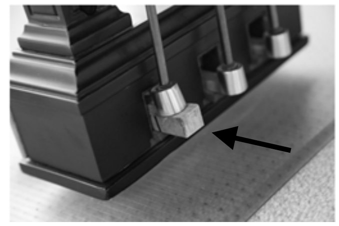
- First, **prop the pedal** up with a wedge



… or place wedge between rod and trapwork lever
… or clamp damper up, away from strings

Prepare

- First, **prop the pedal** up with a wedge



Why?

Measure Downweight (**DW**)

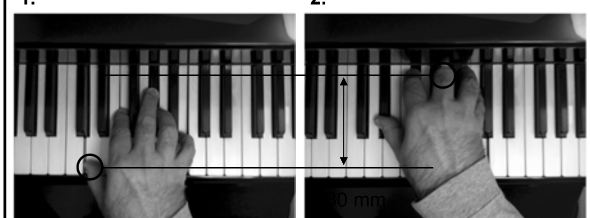
Place the weight so its center is ½" (13 mm) in from the edge of the key top

David Stanwood's Standard Measurement Position (SMP)

Measure Downweight (**DW**)

- Where you measure matters.
  Compare these two **touch points**:

1. **2.**



Measure Downweight (**DW**)

- In a 6' grand the difference might be:

	1.	**2.**
DW	47 g	98 g
UW	23 g	54 g
BW	35 g	76 g
Friction	12 g	22 g
Leverage	5.5 : 1	11.4 : 1
Key dip	10 mm	5.2 mm

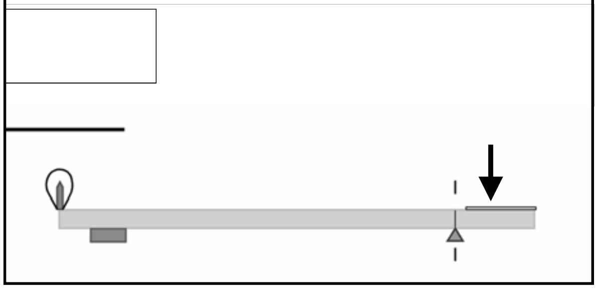
Measure Downweight (**DW**)

Why?

	1.	**2.**
DW	47 g	98 g
UW	23 g	54 g
BW	35 g	76 g
Friction	12 g	22 g
Leverage	5.5 : 1	11.4 : 1
Key dip	10 mm	5.2 mm

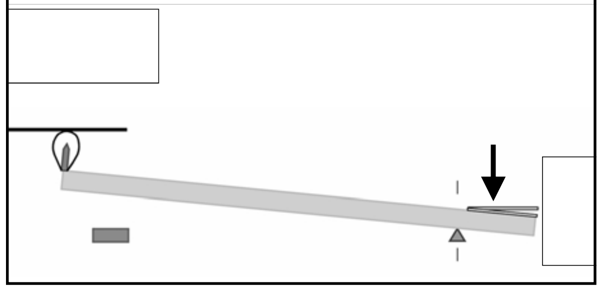
Action as a single lever

Because we are pressing the key here:



Action as a single lever

Because we are pressing the key here:

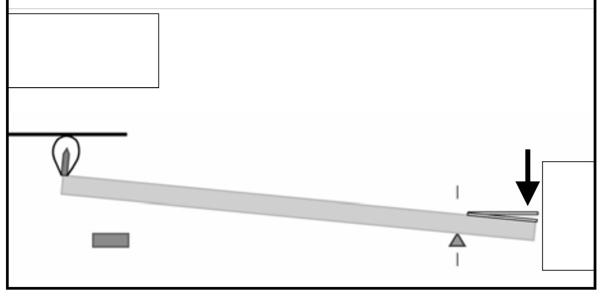


Action as a single lever

… instead of here:

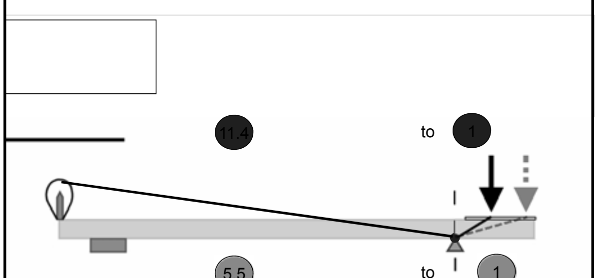
Action as a single lever

… instead of here:



Action as a single lever

… and that more than doubles the leverage ratio:



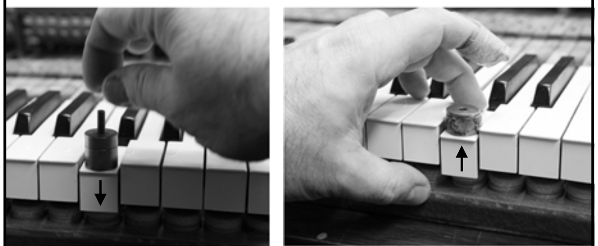
Measure Downweight (**DW**)

Know your weights (can be several grams off)
Pre-depress the key to 4 mm and let go.
The key should sink slowly to about 7 mm.

Measure Upweight (**UW**)

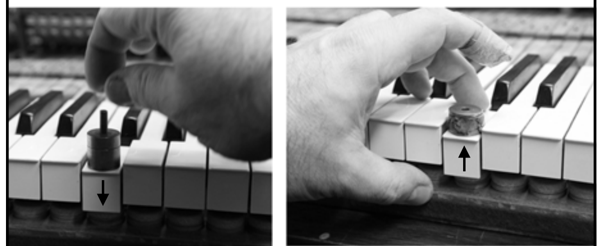
Pre-depress the key against the letoff bump (7-8 mm) and let go.

The key should lift slowly to c. 4 mm dip.



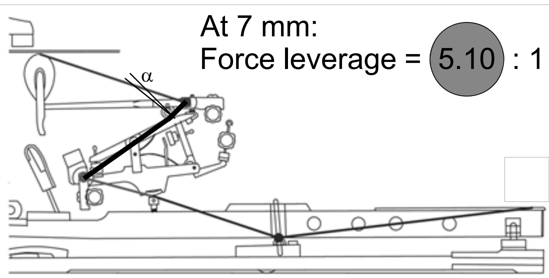
Measure Upweight (**UW**)

We want all measurements to be centered around the 6 mm dip …



Measure Upweight (**UW**)

because at 6 mm dip, force leverage is closest to geometric leverage …



Measuring

Measuring

- Measure/calculate for notes C1, C3, C5, C7:

  Use Touchweight worksheet from *Pianos Inside Out* (p. 277) or fill out:

Note:	C1	C3	C5	C7
DW:				
UW:				
BW:				
F:				

Measuring

- Sample measurements and calculations:

Note:	C1	C3	C5	C7
DW:	52 g			
UW:	22 g			
BW:				
F:				

Measuring

- Sample measurements and calculations:

Note:	C1	C3	C5	C7
DW:	52 g			
UW:	22 g			
BW:	37 g			
F:	15 g			

Measuring

- Sample measurements and calculations:

Note:	C1	C3	C5	C7
DW:	52 g	50 g		
UW:	22 g	26 g		
BW:	37 g			
F:	15 g			

Measuring

- Sample measurements and calculations:

Note:	C1	C3	C5	C7
DW:	52 g	50 g		
UW:	22 g	26 g		
BW:	37 g	38 g		
F:	15 g	12 g		

Measuring

- Sample measurements and calculations:

Note:	C1	C3	C5	C7
DW:	52 g	50 g	47 g	
UW:	22 g	26 g	25 g	
BW:	37 g	38 g		
F:	15 g	12 g		

Measuring

- Sample measurements and calculations:

Note:	C1	C3	C5	C7
DW:	52 g	50 g	47 g	
UW:	22 g	26 g	25 g	
BW:	37 g	38 g	36 g	
F:	15 g	12 g	11 g	

Measuring

- Sample measurements and calculations:

Note:	C1	C3	C5	C7
DW:	52 g	50 g	47 g	48 g
UW:	22 g	26 g	25 g	32 g
BW:	37 g	38 g	36 g	
F:	15 g	12 g	11 g	

Measuring

- Sample measurements and calculations:

Note:	C1	C3	C5	C7
DW:	52 g	50 g	47 g	48 g
UW:	22 g	26 g	25 g	32 g
BW:	37 g	38 g	36 g	40 g
F:	15 g	12 g	11 g	8 g

Calculating balance weight (**BW**)

(DW + UW) / 2 =
(52 + 22) / 2 =
74 / 2 =
37 g

Old Steinway standard: 35 g
(See Rudolf Dietz, *Steinway Reguation*, pp. 36-37)

Recommended: **38 g**
allows reducing **SW** by filing hammers

OK: 33 – 41 g

Calculating friction (**F**)

(DW - UW) / 2 =
(52 - 22) / 2 =
30 / 2 =
15 g

Recommended:

A0: 14 g (OK: 11 – 17 g)

C4: **12 g** (OK: 9 – 15 g)

C8: 10 g (OK: 7 – 13 g)

DW/UW matrix (for note C4)

DW:

UW:		**Low** < 45 g	**High** > 53 g
	Low < 21 g	▪Light ▪Dynamics: either *p* of *f* ▪Poor repetition ▪Dancing keys	▪Resistive (“heavy”) ▪Unresponsive ▪Sluggish ▪High friction
	High > 29 g	▪Flyaway ▪Nothing to bite into ▪Repels fingers ▪Low friction	▪Heavy ▪Hard to play *ppp* ▪Responsive ▪Good repetition

DW/UW matrix (for note C4)

DW:

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	High > 29 g	▪Flyaway ▪Nothing to bite into ▪Repels fingers ▪Low friction	▪Heavy ▪Hard to play *ppp* ▪Responsive ▪Good repetition

?

DW/UW matrix (for note C4)

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	Low < 21 g	▪Light ▪Dynamics: either *p* of *f* ▪Poor repetition ▪Dancing keys	▪Resistive (“heavy”) ▪Unresponsive ▪Sluggish ▪High friction
	High > 29 g	▪Flyaway ▪Nothing to bite into ▪Repels fingers ▪Low friction	▪Heavy ▪Hard to play *ppp* ▪Responsive ▪Good repetition

leads

DW/UW matrix (for note C4)

DW: (columns) / **UW**: (rows)

	Low < 45 g	**High** > 53 g
Low < 21 g	▪Light ▪Dynamics: either *p* of *f* ▪Poor repetition ▪Dancing keys	▪Resistive (“heavy”) ▪Unresponsive ▪Sluggish ▪High friction
High > 29 g	▪Flyaway ▪Nothing to bite into ▪Repels fingers ▪Low friction	▪Heavy ▪Hard to play *ppp* ▪Responsive ▪Good repetition

?

DW/UW matrix (for note C4)

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High > 29 g	▪Flyaway ▪Nothing to bite into ▪Repels fingers ▪Low friction	▪Heavy ▪Hard to play *ppp* ▪Responsive ▪Good repetition

friction

How to Rebalance the Action?

How to rebalance the action?

- Alter strike weight (**SW**)
  (changes tone, inertia):
  - File hammers
  - Thin/taper the hammers
  - Replace hammers (lighter/heavier)
  - Add clips
  - Install lead wire
- Change the action leverage ratio (**R**)
  (changes key dip, inertia)
- Add or remove key leads (alter **FW**)
  (no significant change in inertia)
- TouchRail, wippen (“turbo”) springs, magnets
  (no change in inertia)

big topics for another time!

Limits of static action balancing

- No idea about inertial effects of a particular configuration
- Doesn’t suggest what to “fix”
- Only focused on *ppp* response
- Friction can be unbalanced and misleading

Always consider *all* aspects of touch adjustment, not just static balancing

What Are We Measuring?

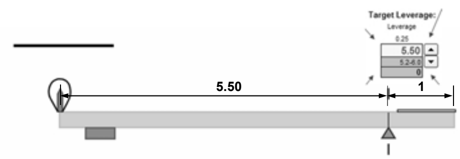
What are we measuring?

Because the action is laid horizontally, we can measure forces as weights.

To simplify, we treat rotational forces (torque) as linear, vertical forces

What are we measuring?

In this example, the action has a leverage ratio of 5.5 : 1:

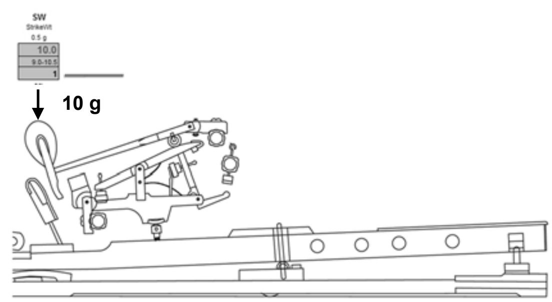


What are we measuring?

On the back end, the key lifts the **SW** (hammer strike weight):

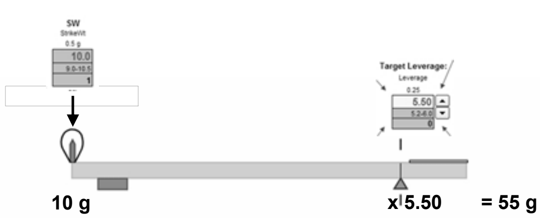
What are we measuring?

On the back end, the key lifts the **SW** (hammer strike weight):



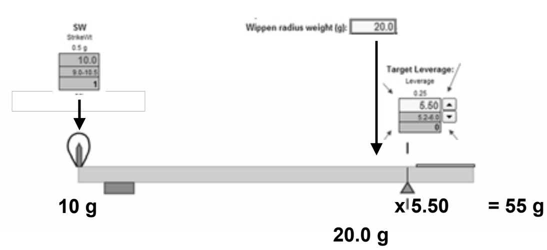
What are we measuring?

To balance the SW, the weight needed on the other end is 55 g:



What are we measuring?

The back segment also carries the **WW** (wippen weight):



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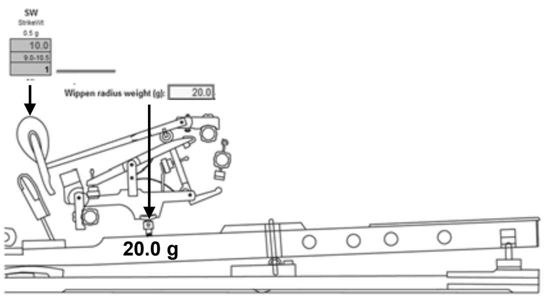
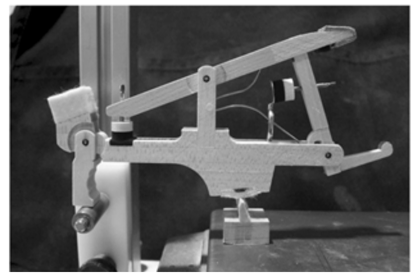


What are we measuring?

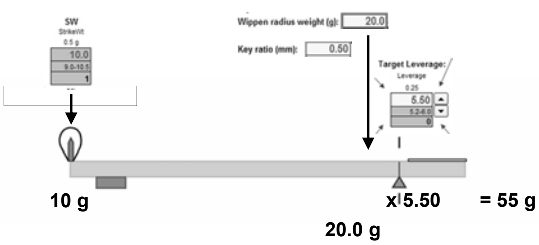
Measuring
the **WW** (wippen weight):

Photo by Jude Reveley, RPT



What are we measuring?

WW (wippen weight) acts on the
key with the key leverage ratio of
approx. 0.5 : 1:



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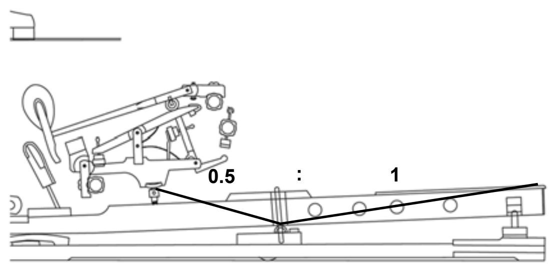
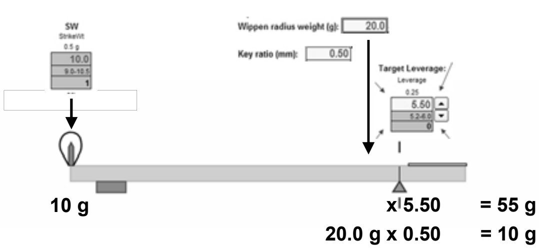


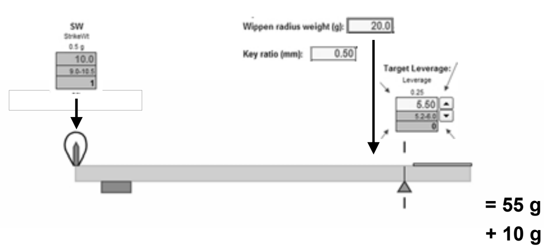
What are we measuring?

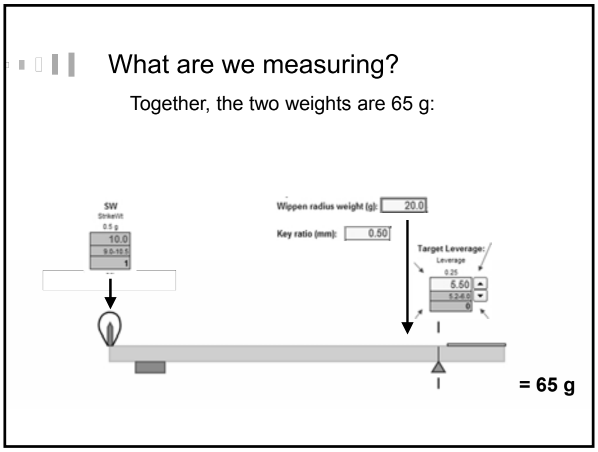
… adding 10 grams to the front end:

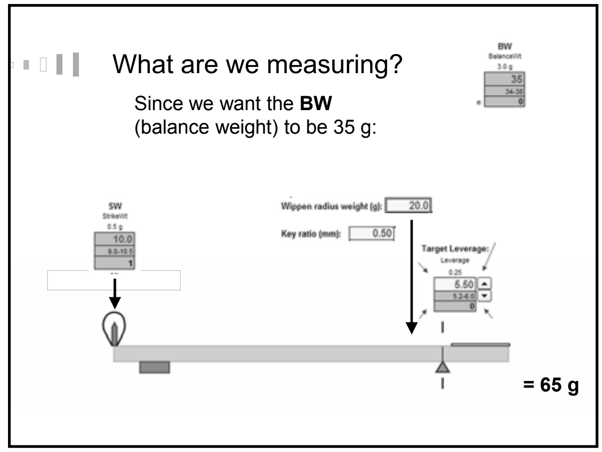


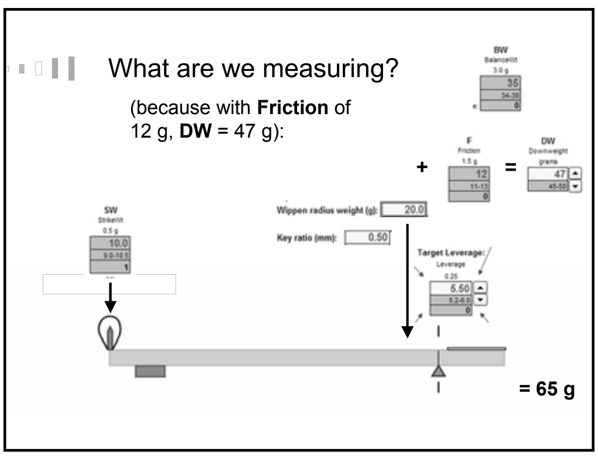
What are we measuring?

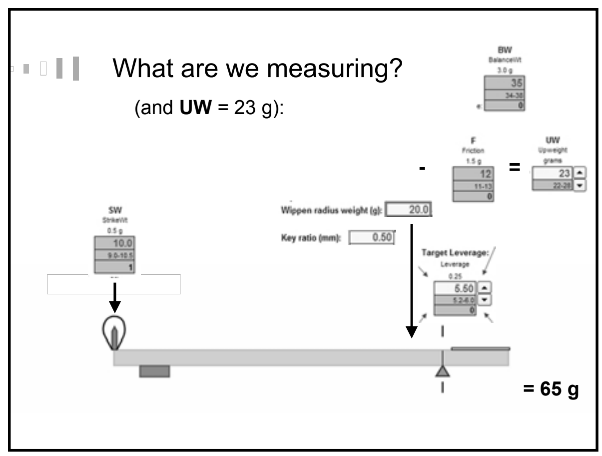
Together, the two weights are:

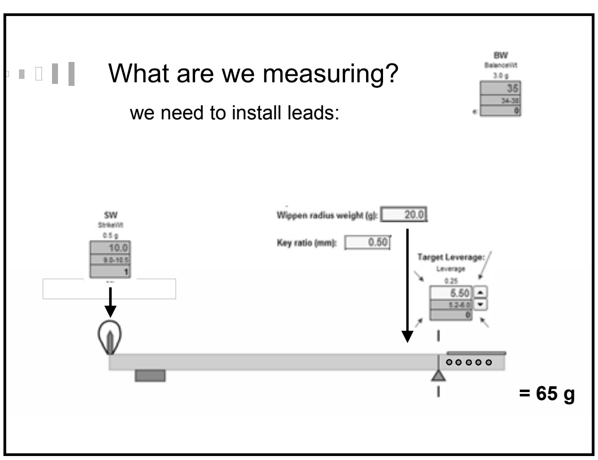


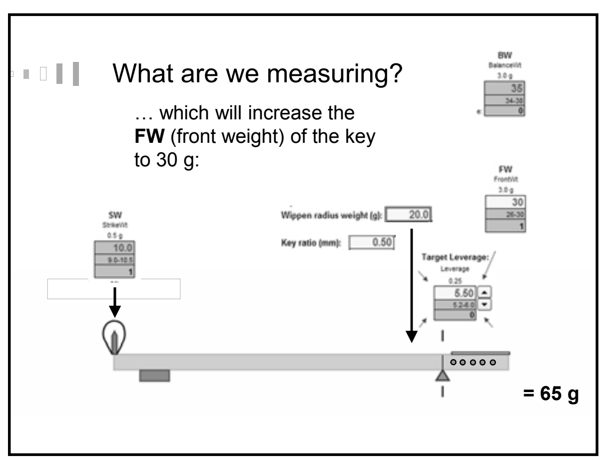

What are we measuring?
Together, the two weights are 65 g:
SW
StrikeWt
10.0
Wippen radius weight (g):
20.0
Key ratio (mm):
0.50
Target Leverage:
Leverage
5.50
= 65 g


What are we measuring?
Since we want the **BW**
(balance weight) to be 35 g:
BW
BalanceWt
35
SW
StrikeWt
10.0
Wippen radius weight (g):
20.0
Key ratio (mm):
0.50
Target Leverage:
Leverage
5.50
= 65 g


What are we measuring?
(because with **Friction** of
12 g, **DW** = 47 g):
BW
BalanceWt
35
+
F
Friction
12
=
DW
Downweight
grams
47
SW
StrikeWt
10.0
Wippen radius weight (g):
20.0
Key ratio (mm):
0.50
Target Leverage:
Leverage
5.50
= 65 g

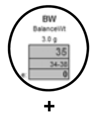

What are we measuring?
(and **UW** = 23 g):
BW
BalanceWt
35
-
F
Friction
12
=
UW
Upweight
grams
23
SW
StrikeWt
10.0
Wippen radius weight (g):
20.0
Key ratio (mm):
0.50
Target Leverage:
Leverage
5.50
= 65 g

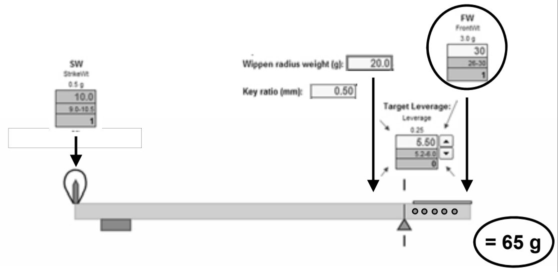

What are we measuring?
we need to install leads:
BW
BalanceWt
35
SW
StrikeWt
10.0
Wippen radius weight (g):
20.0
Key ratio (mm):
0.50
Target Leverage:
Leverage
5.50
= 65 g


What are we measuring?
… which will increase the
FW (front weight) of the key
to 30 g:
BW
BalanceWt
35
FW
FrontWt
30
SW
StrikeWt
10.0
Wippen radius weight (g):
20.0
Key ratio (mm):
0.50
Target Leverage:
Leverage
5.50
= 65 g

What are we measuring?

… so that the sum of **BW** and **FW** is 65 g:



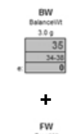


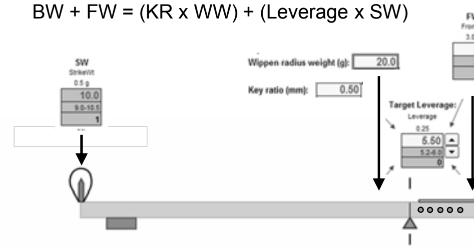
= 65 g

What are we measuring?

And *that* is David Stanwood's equation of balance:

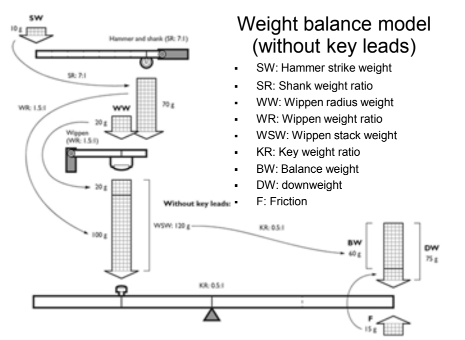
BW + FW = (KR x WW) + (Leverage x SW)





= 65 g

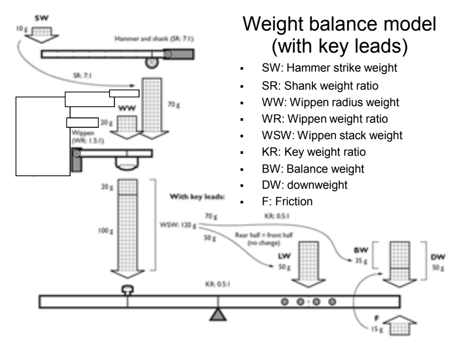
What are we measuring?



Weight balance model (without key leads)

- SW: Hammer strike weight
- SR: Shank weight ratio
- WW: Wippen radius weight
- WR: Wippen weight ratio
- WSW: Wippen stack weight
- KR: Key weight ratio
- BW: Balance weight
- DW: downweight
- F: Friction

What are we measuring?



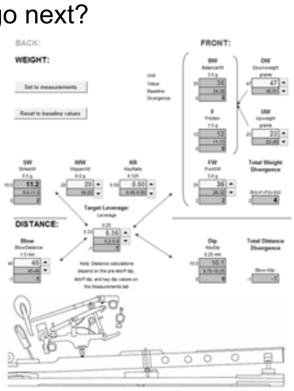
Weight balance model (with key leads)

- SW: Hammer strike weight
- SR: Shank weight ratio
- WW: Wippen radius weight
- WR: Wippen weight ratio
- WSW: Wippen stack weight
- KR: Key weight ratio
- BW: Balance weight
- DW: downweight
- F: Friction

Where to go next?

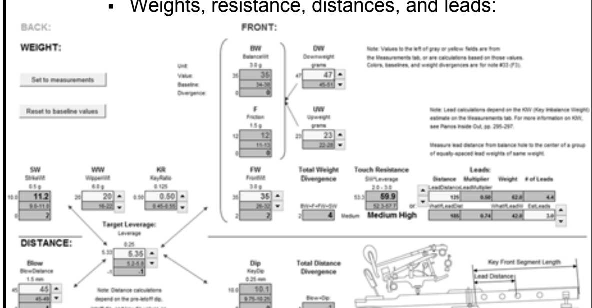
- Free Practical Touch Analysis calculator

http://pianosinsideout.com/Bonus.html:



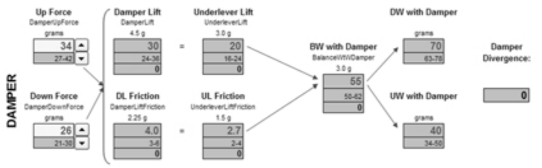
Practical Touch Analysis calculator

- Weights, resistance, distances, and leads:



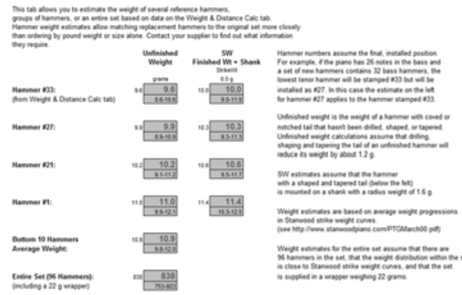
Practical Touch Analysis calculator

- Effect of dampers on touch:



Practical Touch Analysis calculator

- Hammer weight estimates:



Where to Go Next

- In US: **David Stanwood**:
  Training, certification (http://www.stanwoodpiano.com/)
- In Europe: **PTDAE**
  Precision Touch Design Academy Europe
  (http://ptdae.com)
- Stay tuned for **Practical Touch Adjustment** system (pianosinsideout.com/Bonus)

Thank you!

www.pianosinsideout.com/Classes