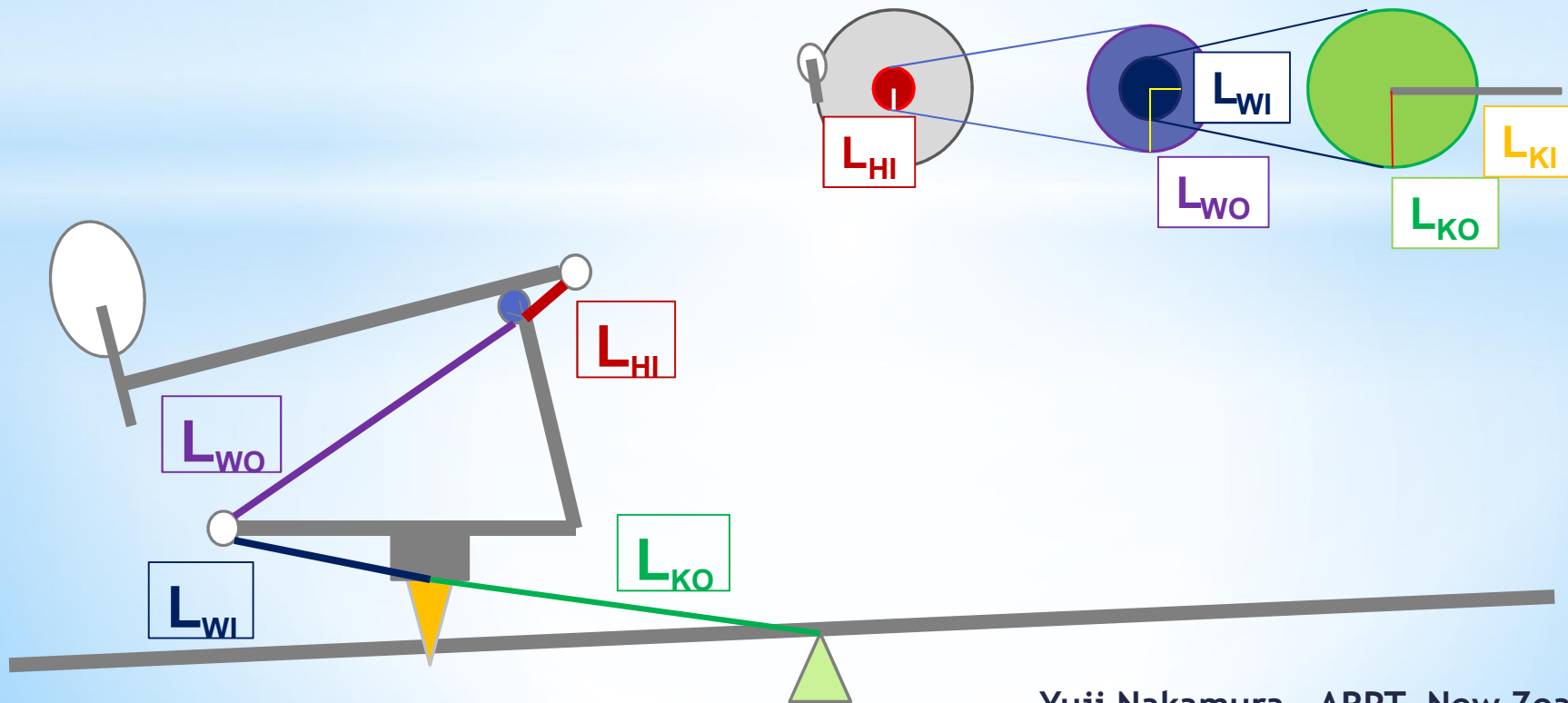


Understanding “Moment of Inertia”



Traditional “Touch Weight”

is indicated by combination of
Down weight and Up weight

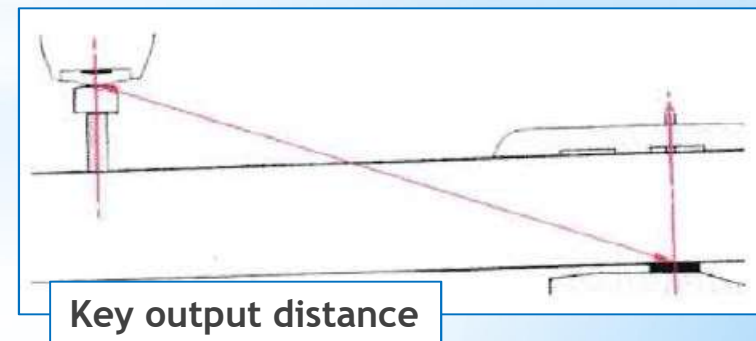
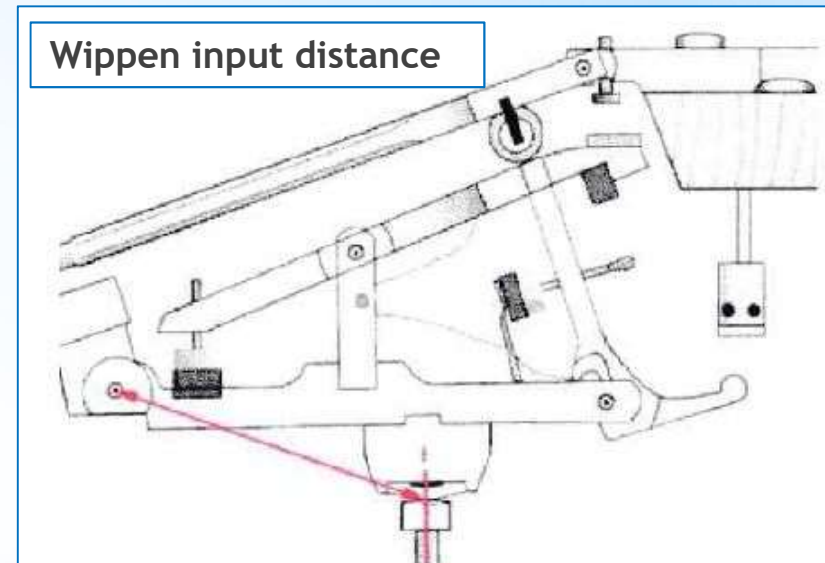
Example: $DW = 52 \text{ g}$ & $UW = 26 \text{ g}$

Dynamic Touchweight

Touch weight felt while playing

“Measurement of DW & UW
doesn't stand actual playing as
they were measured by movement
at less than pp playing”

Approach to inertial effect in the piano action by **Darren Fandrich & John Rhodes**



Approach to adjust inertial effect in the piano action

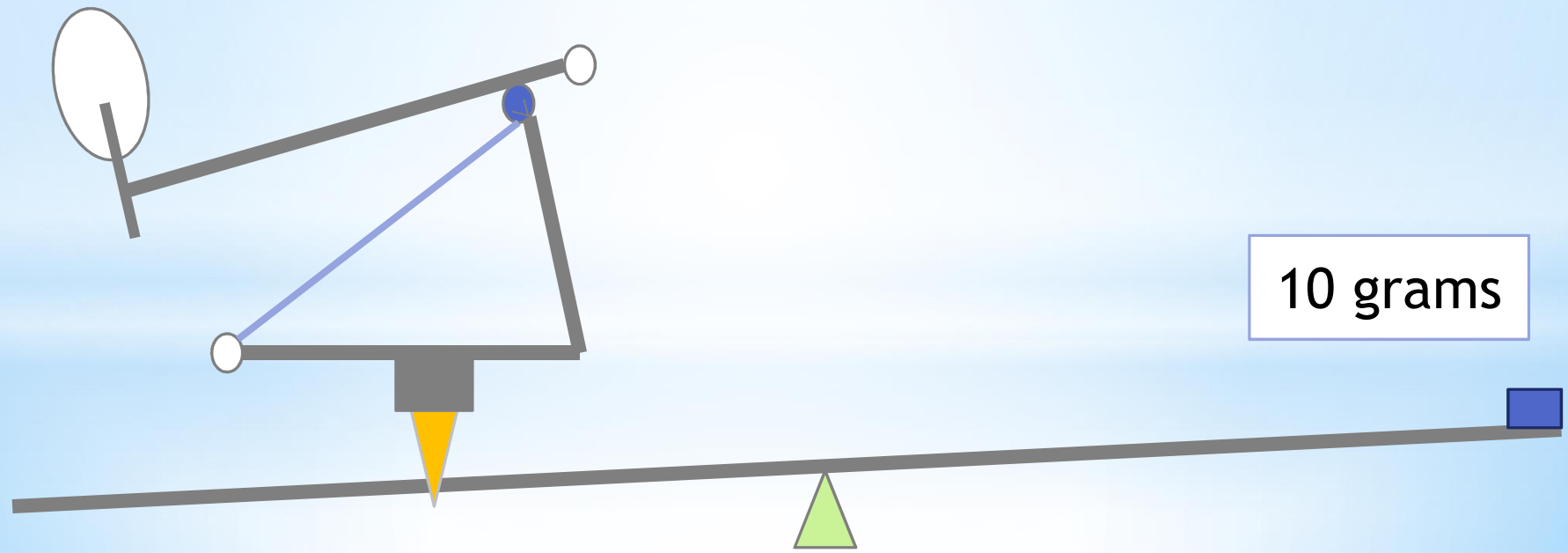
“Touch Weight Management”

- Manage two indexes together;
 - static “**Balance Weight**” and
 - kinetic resistance “**Moment of Inertia**”
- Understand theory to manage touchweight

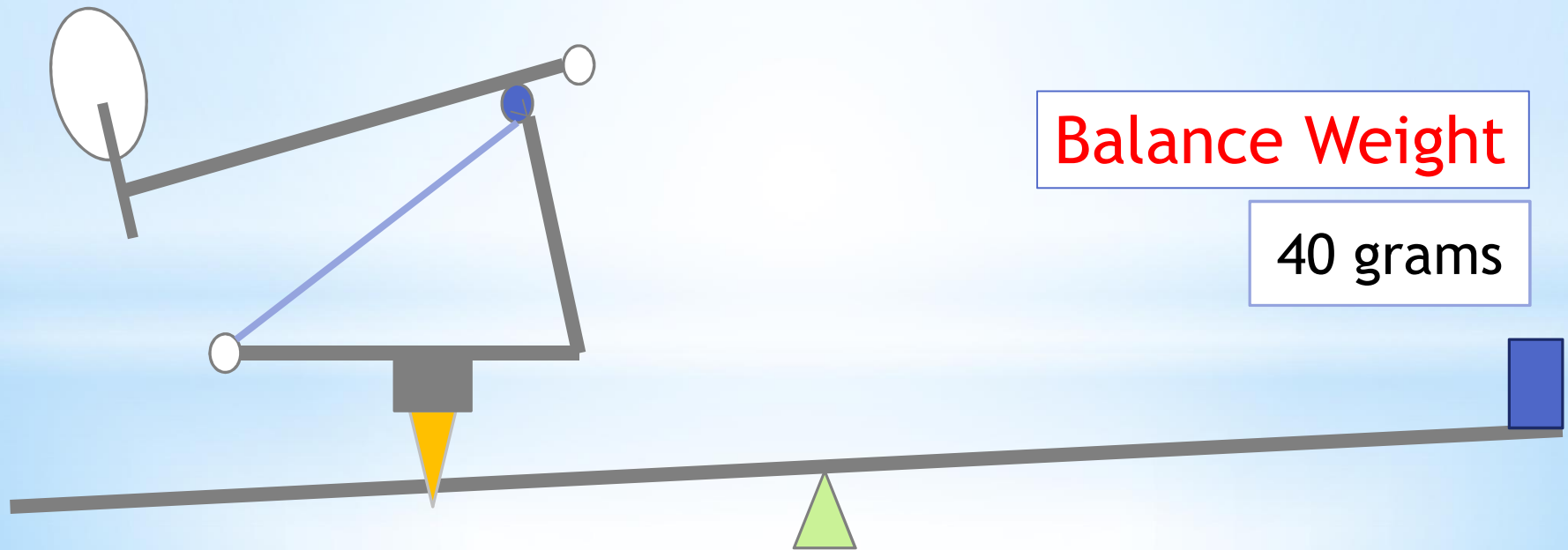
Components of Touch Weight

- **Balance weight**
- **Friction weight**
- **Additional torque**
(= Moment of Inertia x angular acceleration)

Elements of Touch Weight



Balanced Action



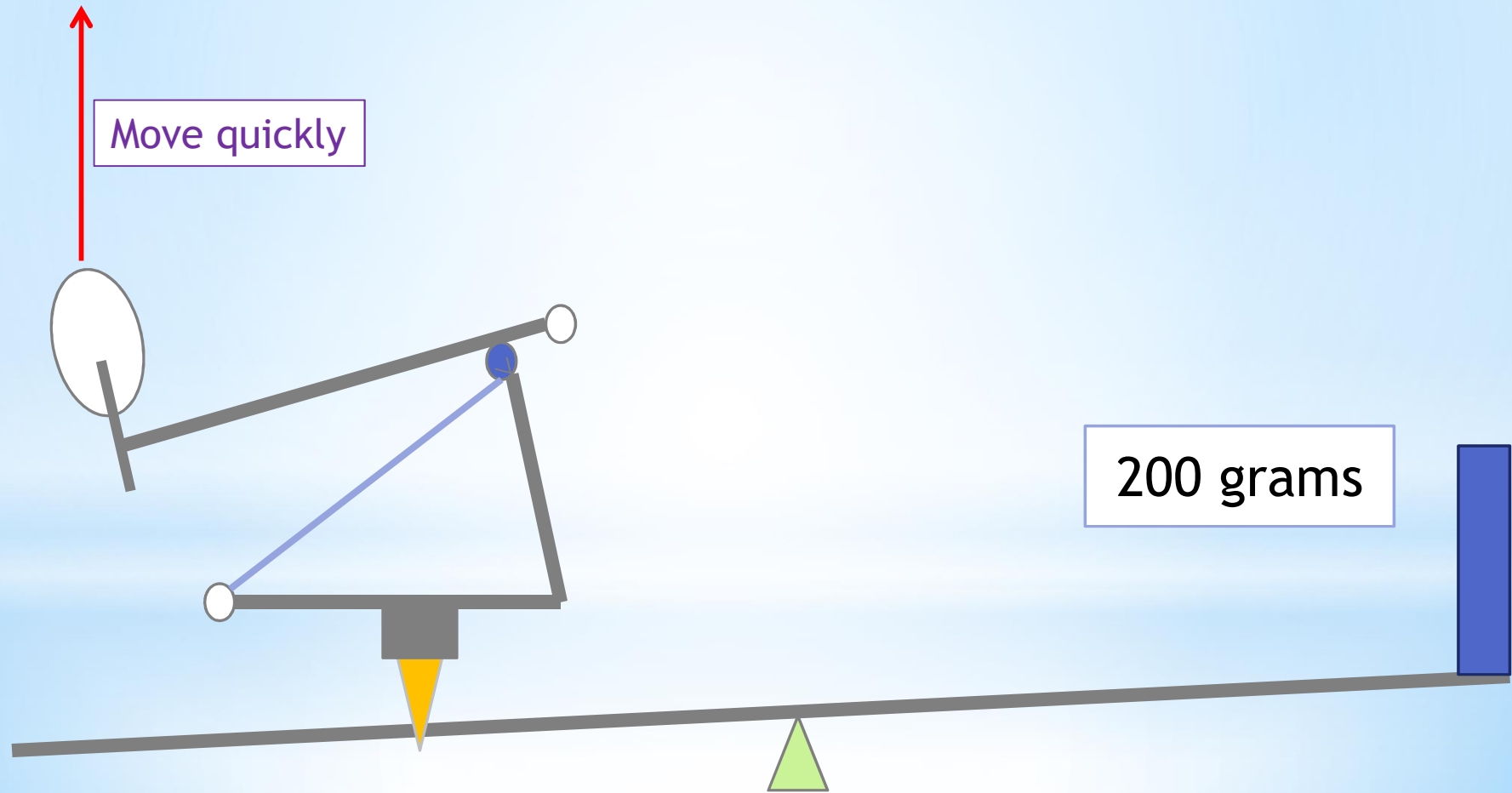
Down Weight

Balance Weight (40g) + Friction (10g)



Louder (forte)

BW (40g) + F (10g) + More Additional torque (150g)



Example of heavy touch (1)

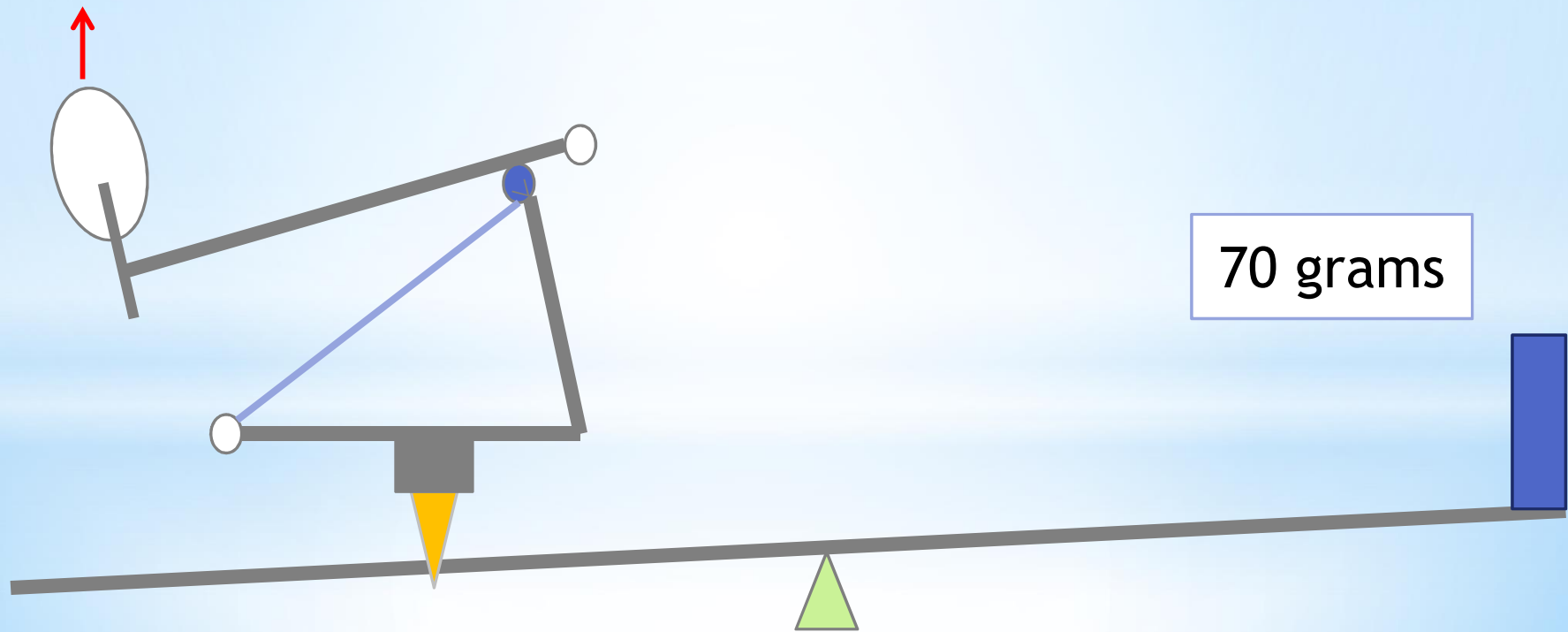
1, Heavy BW , Normal Friction , Normal Mol

BW = 60 g (DW 70 g & UW 50 g), F = 10 g

By different weight

At BW (40g) & F (10g): Move moderately with 20g of additional torque

At BW(60g) & F (10g): Move slowly like Down Weight measurement



Example of heavy touch (2)

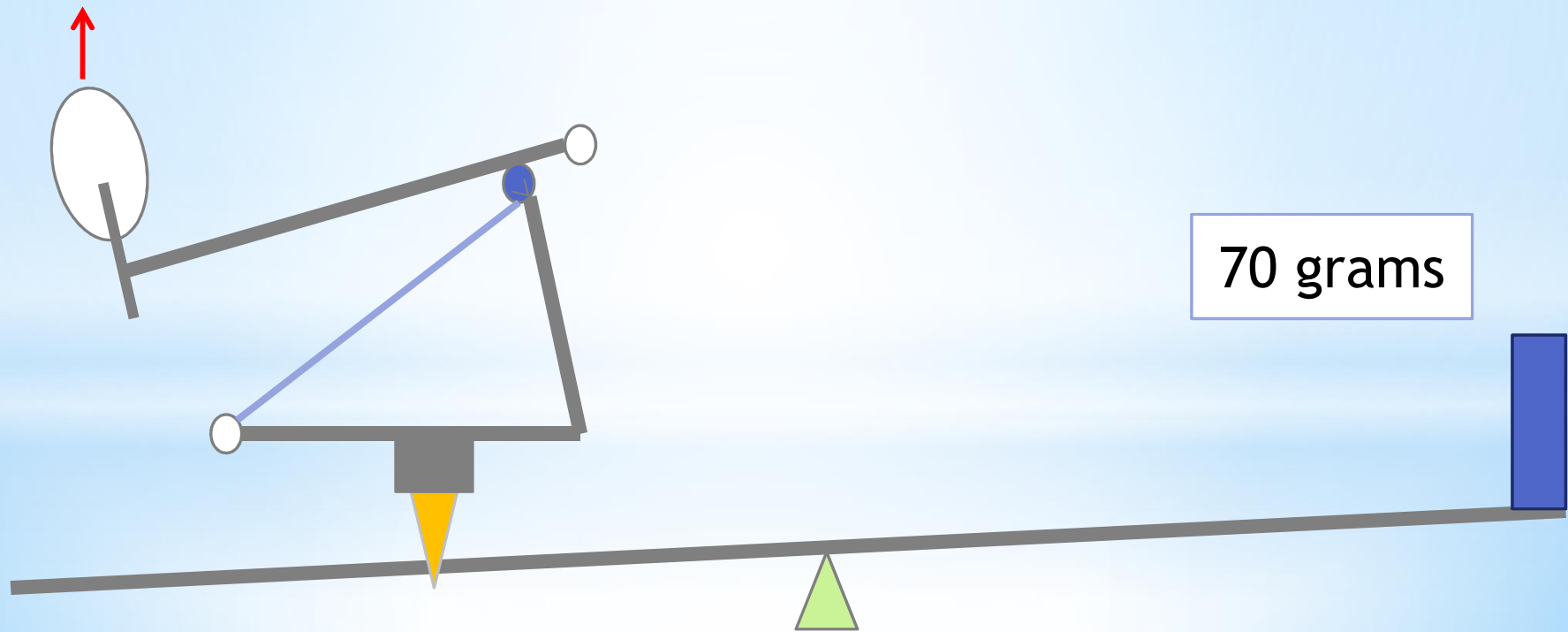
2, Moderate BW , **Big Friction** , **Normal Mol**

BW = 40 g (DW 70 g & UW 10 g, F = 30 g)

Sticky action

At BW (40g) & F (10g): Move moderately with 20g of additional torque

At BW(40g) & F (30g): Move slowly like Down Weight measurement



Example of heavy touch (3)

3, Moderate BW , Normal Friction , Big Mol

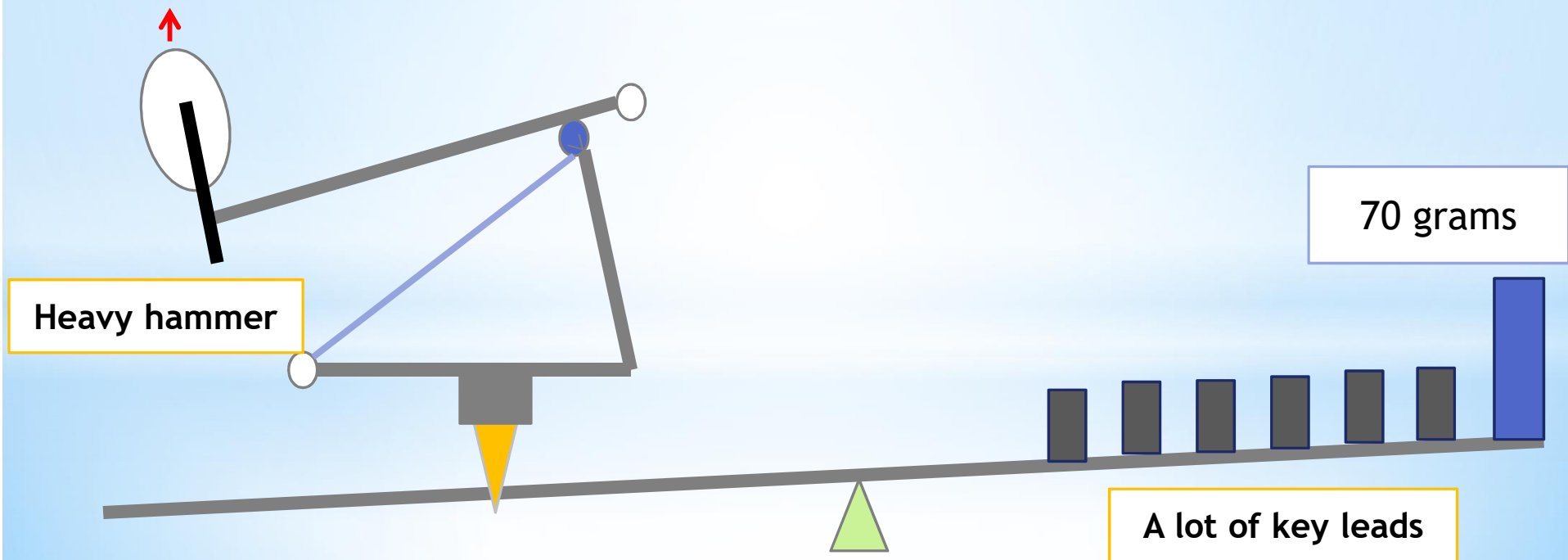
BW = 40 g (DW 50 g & UW 30 g), F = 10 g and

heavy hammer with a lot of key leads

Somehow feel heavy

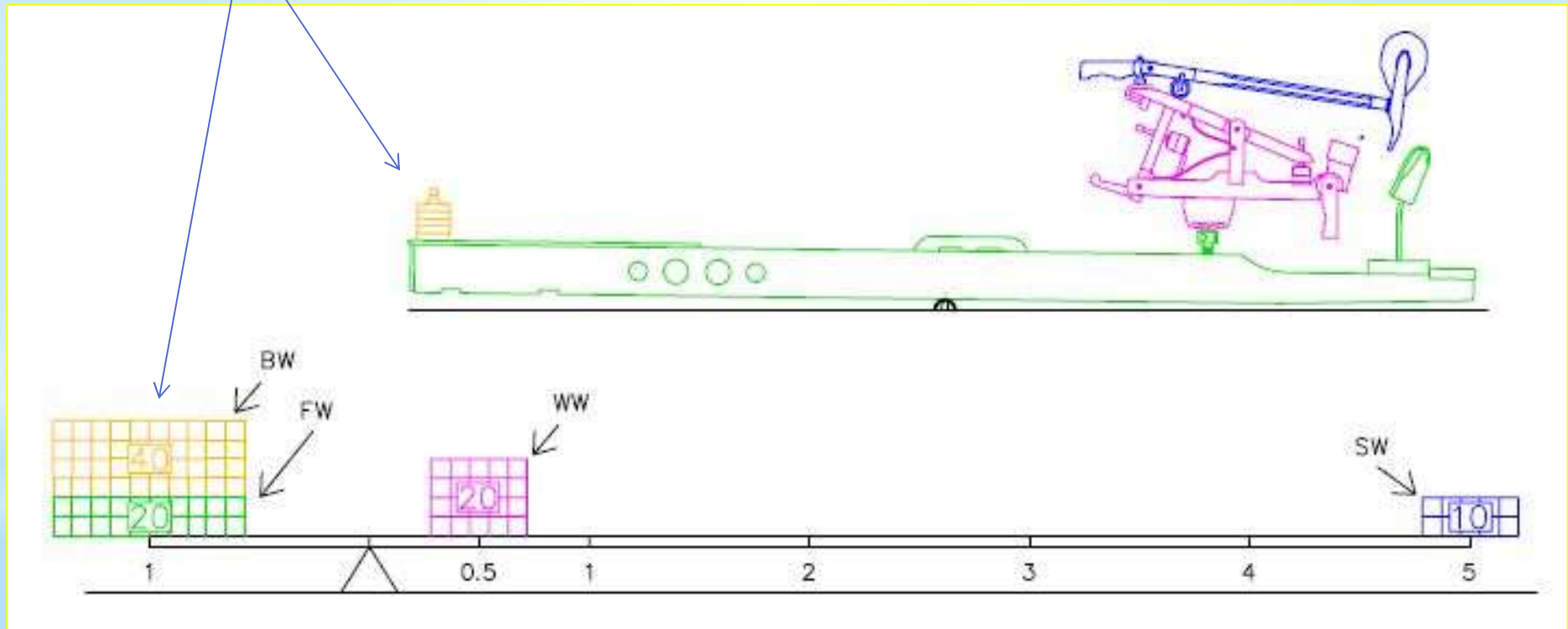
At BW (40g) & F (10g): Move moderately with 20g of additional torque

At BW(40g) & F (10g): Less acceralation with 20g of additional torque



What is “Balance Weight”

$$\mathbf{BW} + \mathbf{FW} = \mathbf{WW} \times \mathbf{KR} + \mathbf{HSW} \times \mathbf{SR}$$

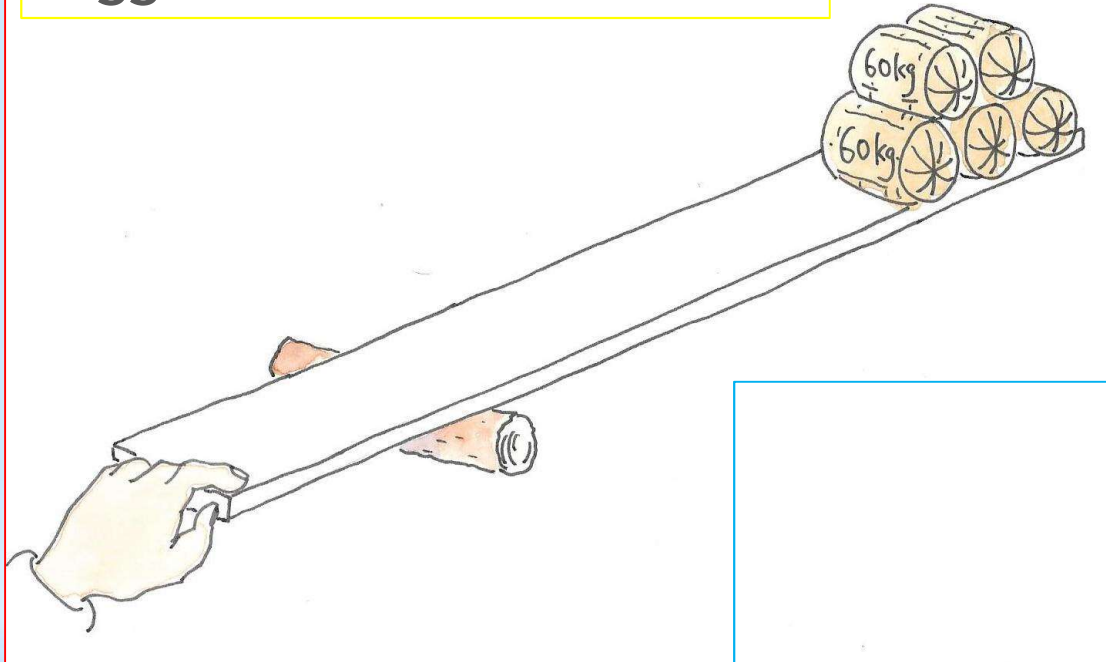


$$\mathbf{BW} = (\mathbf{DW} + \mathbf{UW}) / 2$$

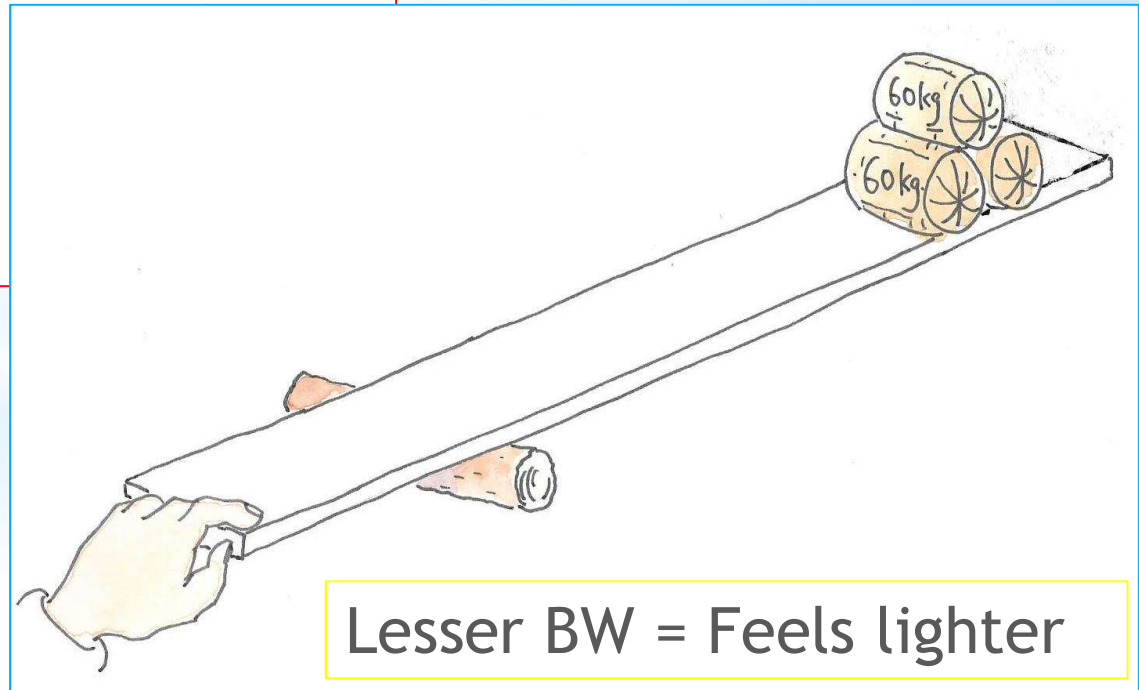
Seesaw model by David Stanwood

Static touchweight: Balance Weight

Bigger BW = Feels heavier



Lesser BW = Feels lighter

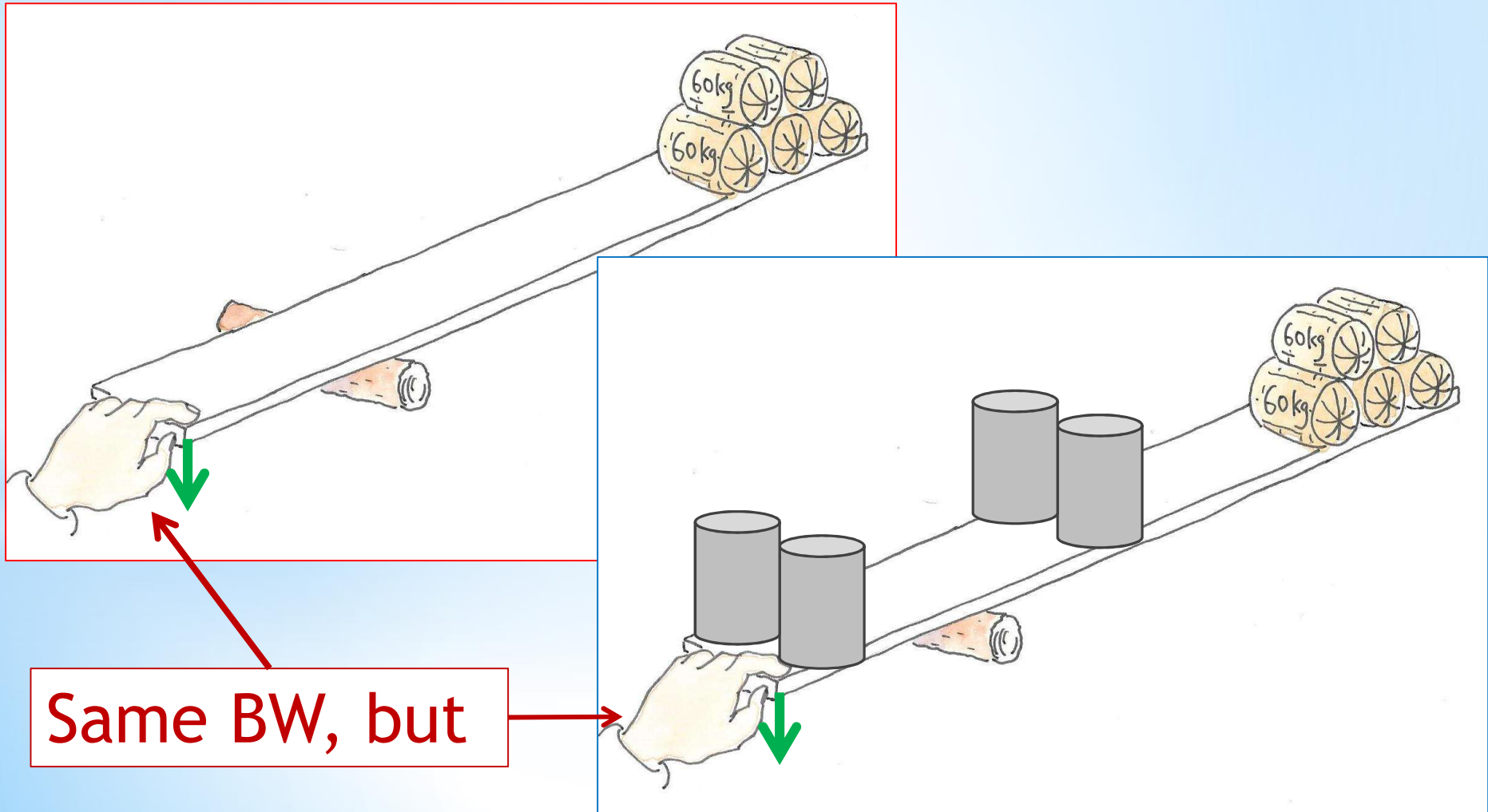


Causes of Friction

- Flange centers
- Key bushing (balance & front)
- Key balance hole
- Capstan - heel connection
- knuckle - jack connection

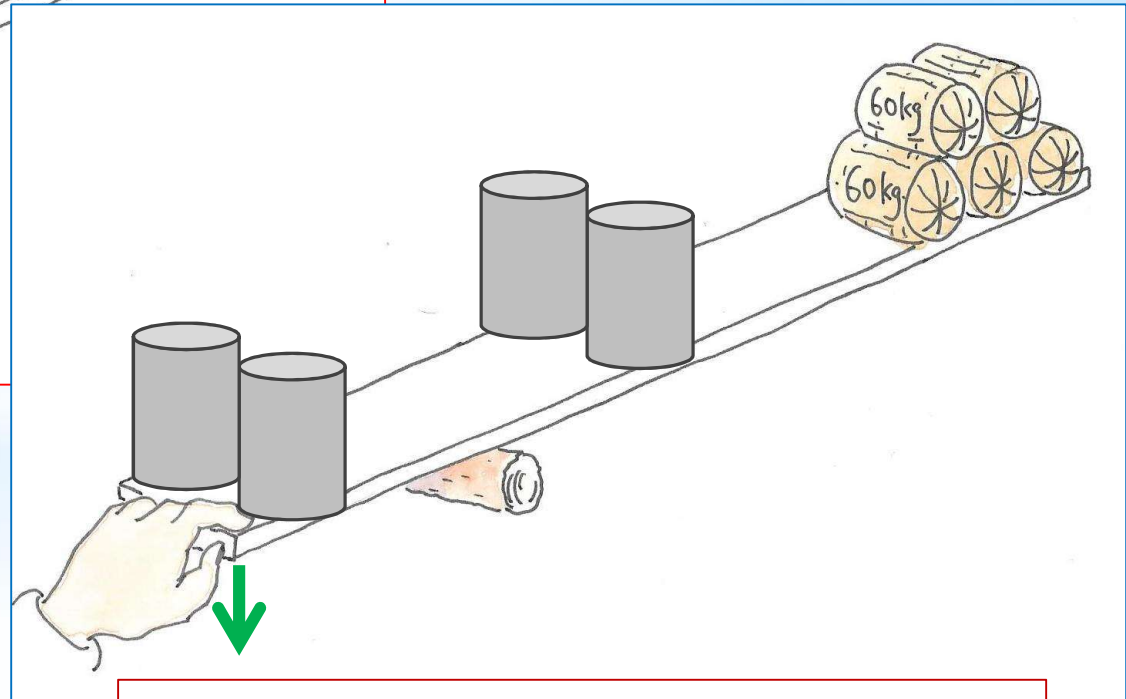
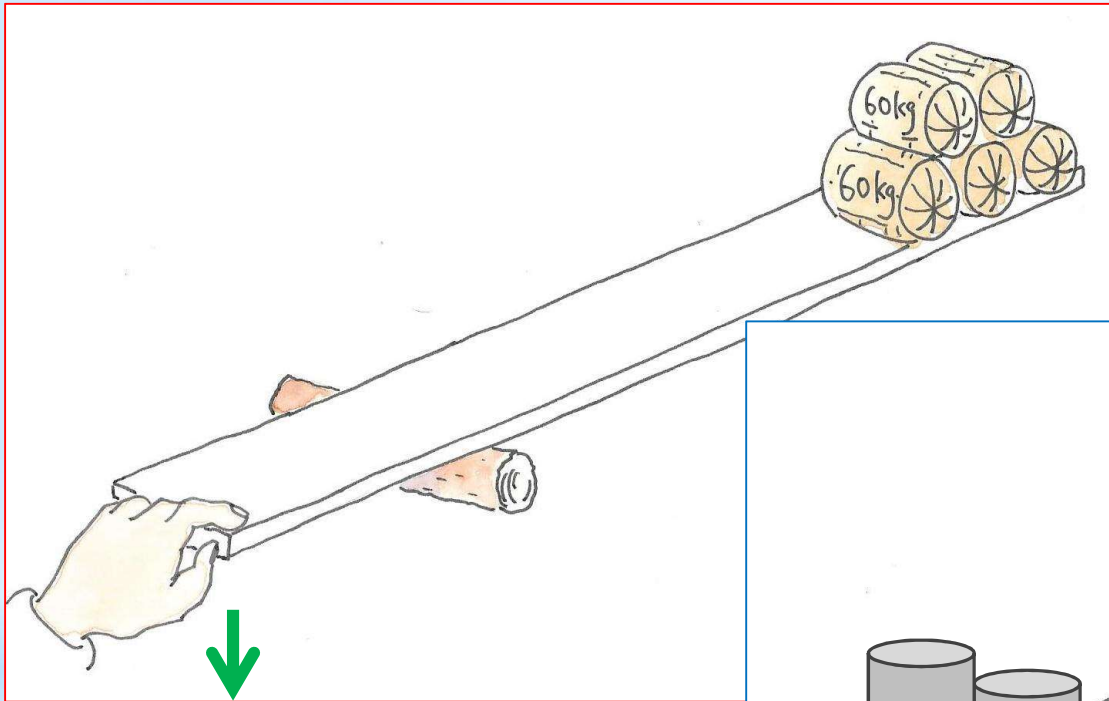
Kinetic Touch Weight

Same BW doesn't mean they feel same "touch weight"



Kinetic Touch Weight

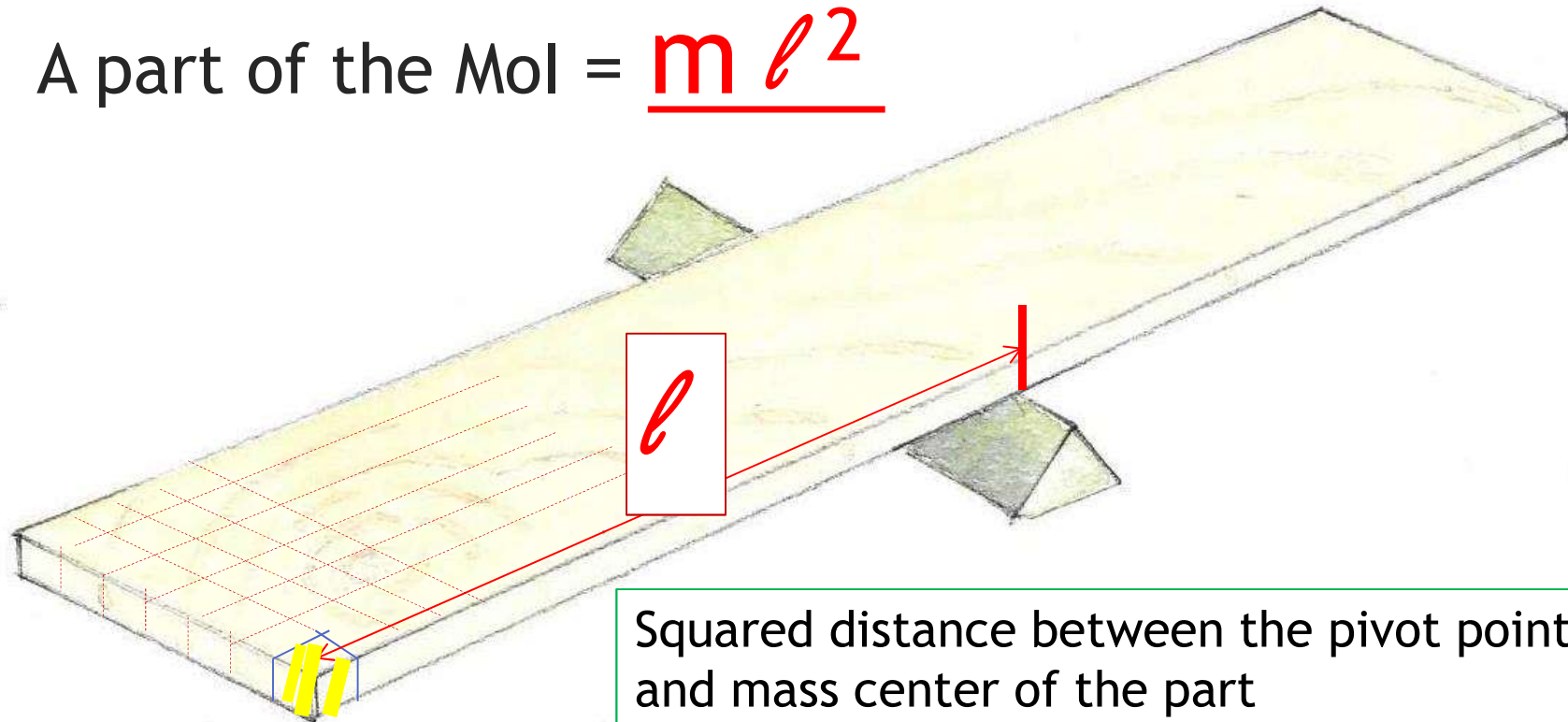
Torque = Moment of Inertia x angular acceleration



More Mol → Less acceleration

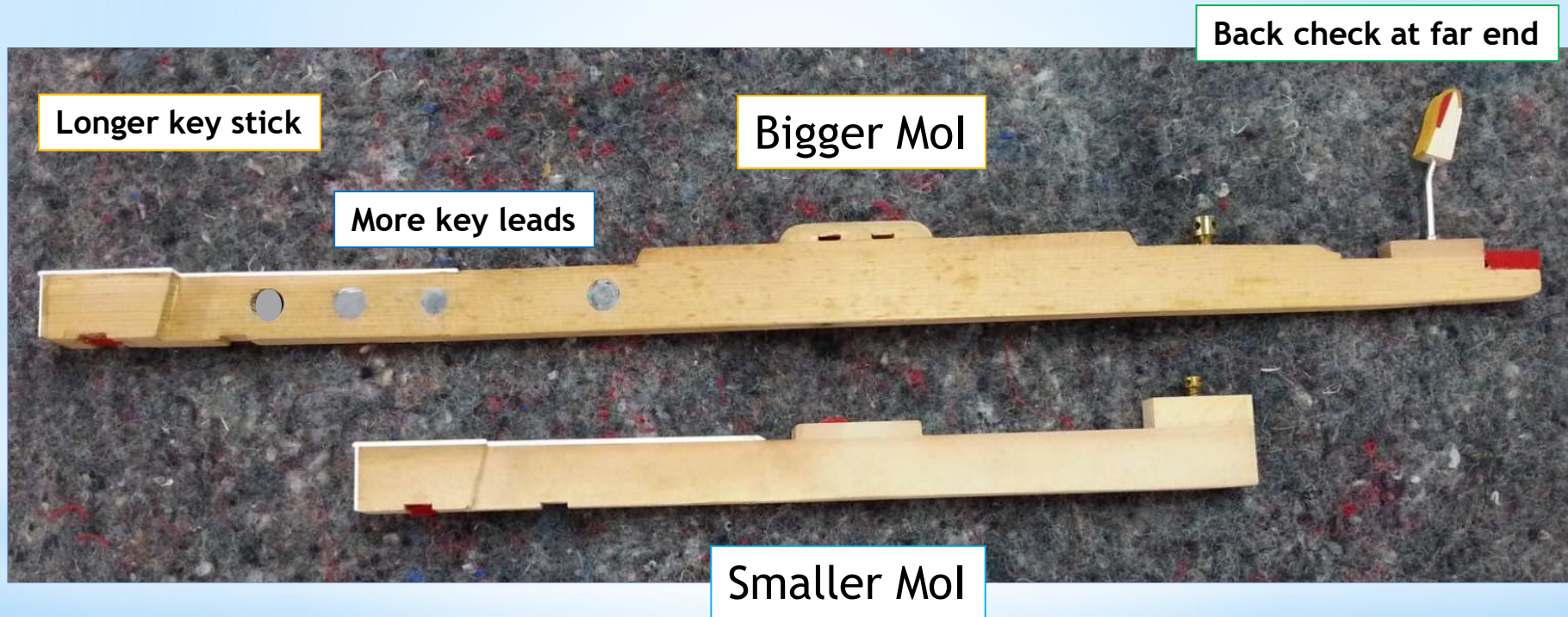
How to calculate Mol

A part of the Mol = $m \ell^2$

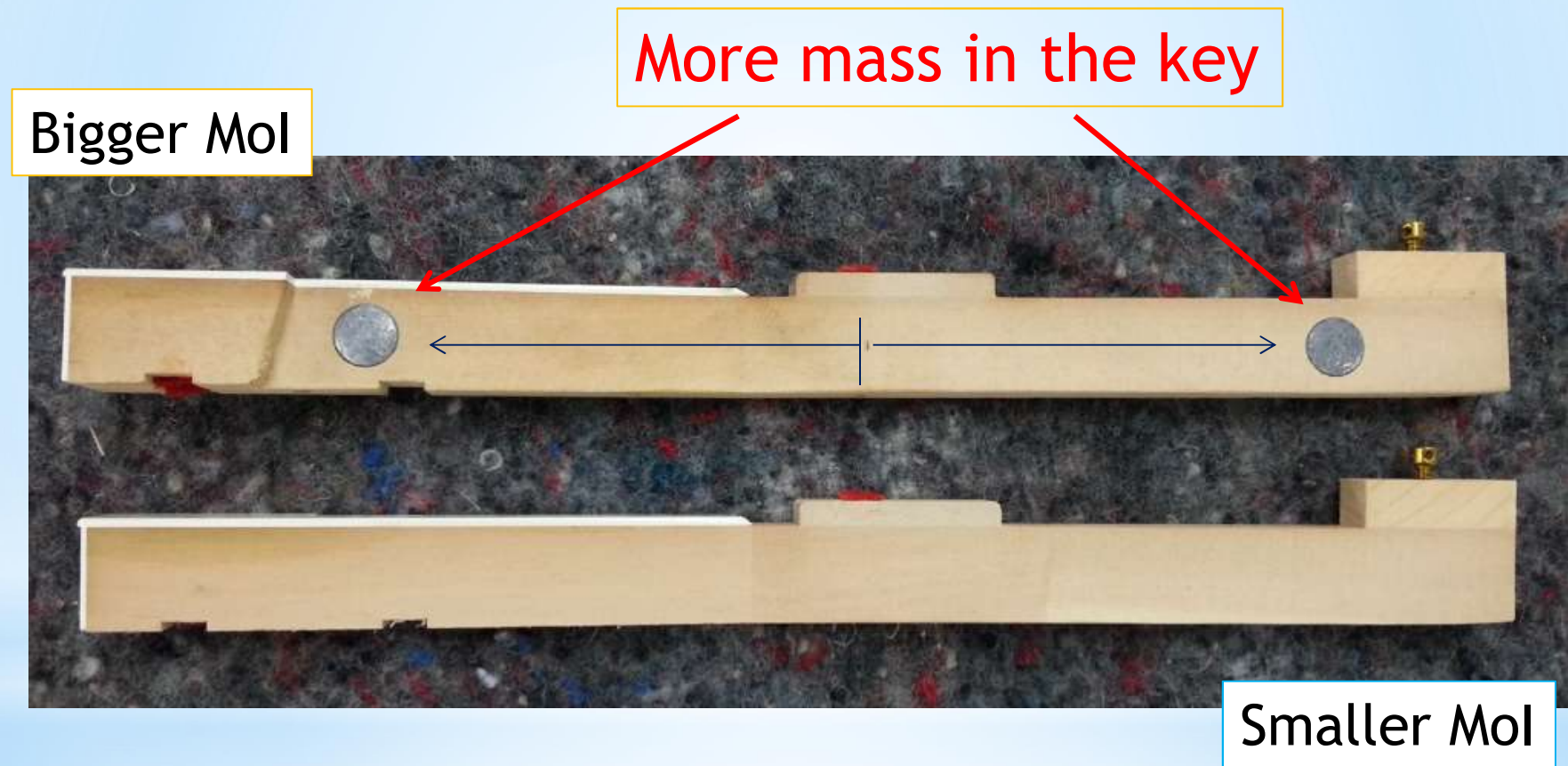


m : Mass of a part

Compare two keys with different length



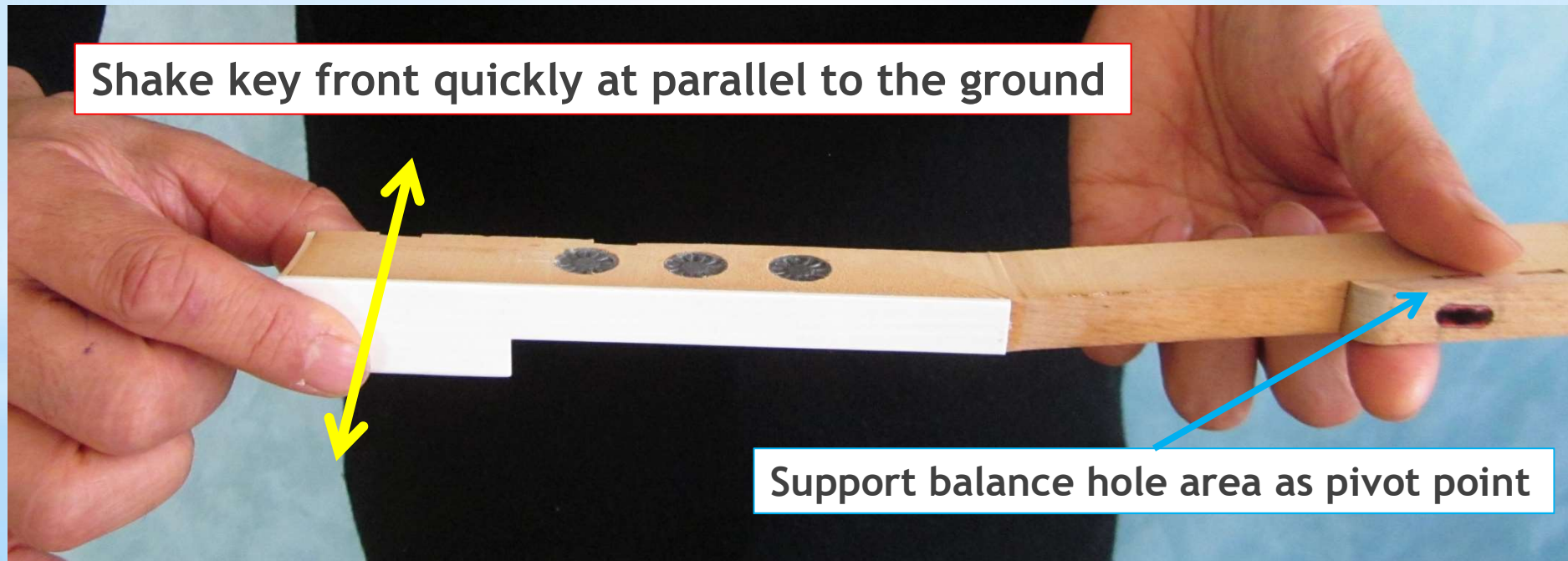
Compare two keys with same length



Experience Mol of a key stick

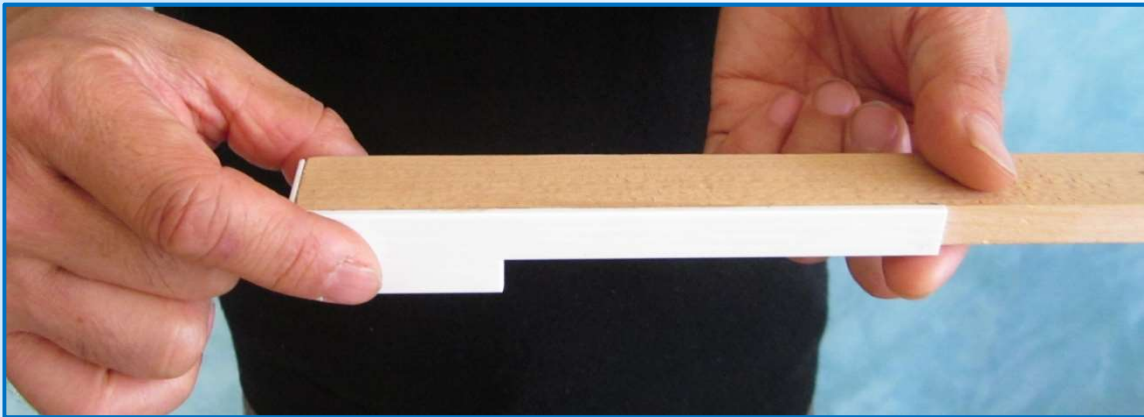
What do you feel when giving torque to the key?

Resistance of movement = Moment of Inertia



Compare the Mol of two keys

Which do you feel more resistance when rotating?



Short & no lead
➤ upright



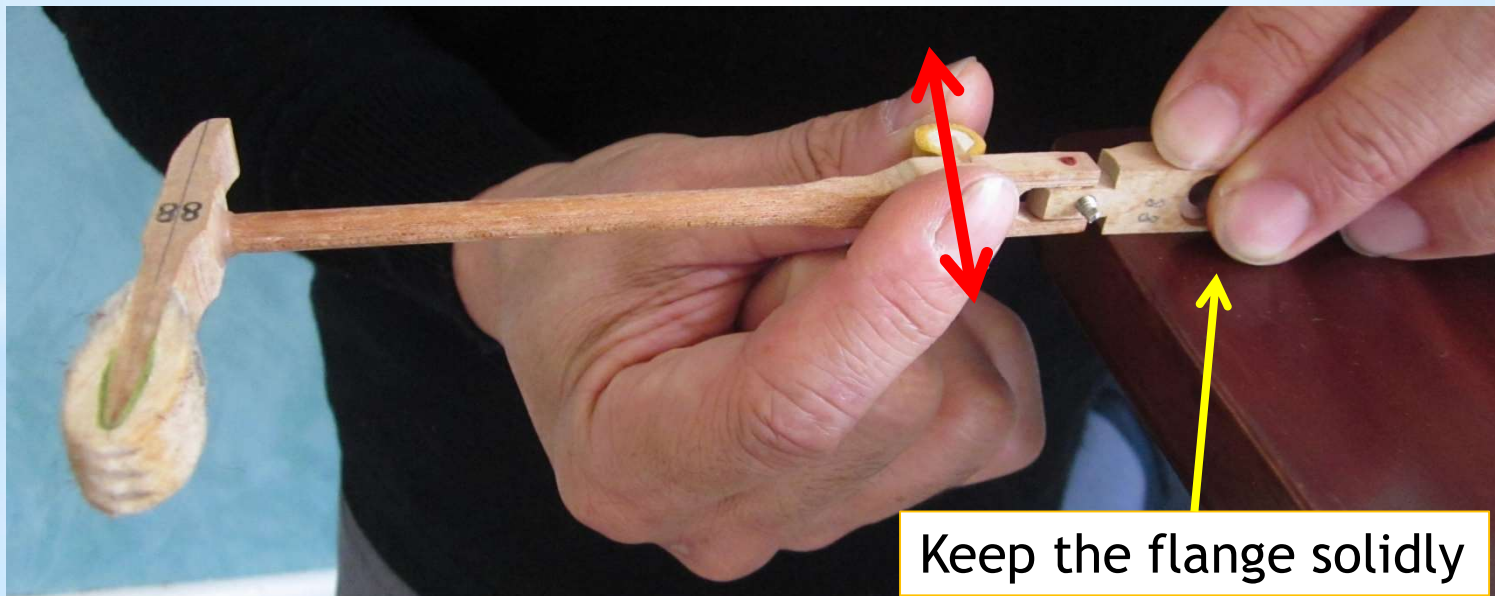
Long & some leads
➤ grand

Experience Mol of a hammer

What do you feel when giving torque to the knuckle?

Resistance of rotation = Mol of the hammer

Give force at the knuckle forward and backward quickly
at parallel to the ground



Compare the Mol of two hammers



Treble hammer



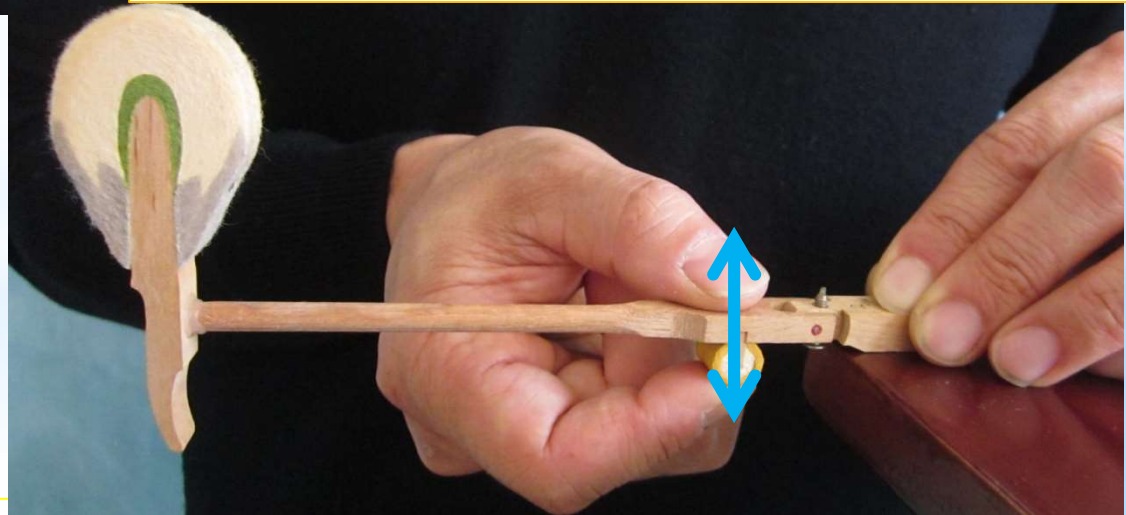
Bass hammer

Hammers at vertical movement

1, Support at under the knuckle. Feel static balance weight.



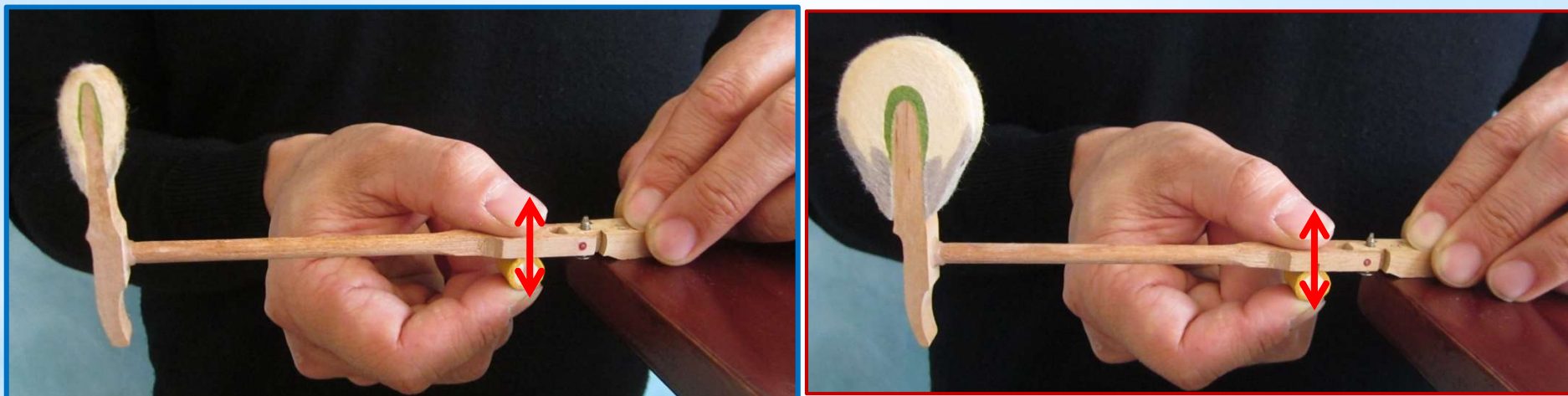
2, Move the hammer up & down rapidly.



Need additional power when moving up

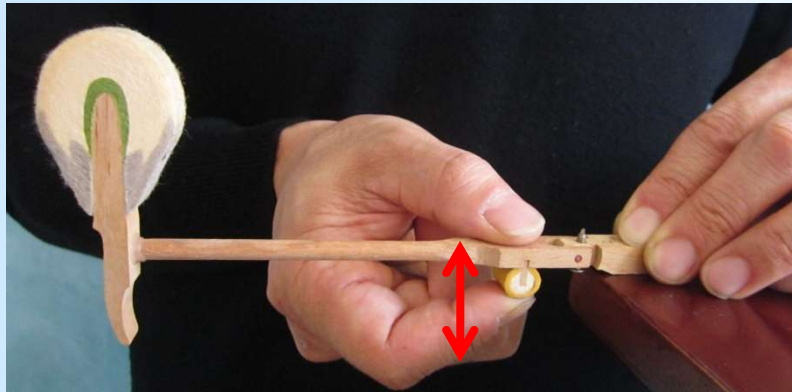
Bass vs. Treble

- ❖ Try tremolo at treble hammer and bass hammer.

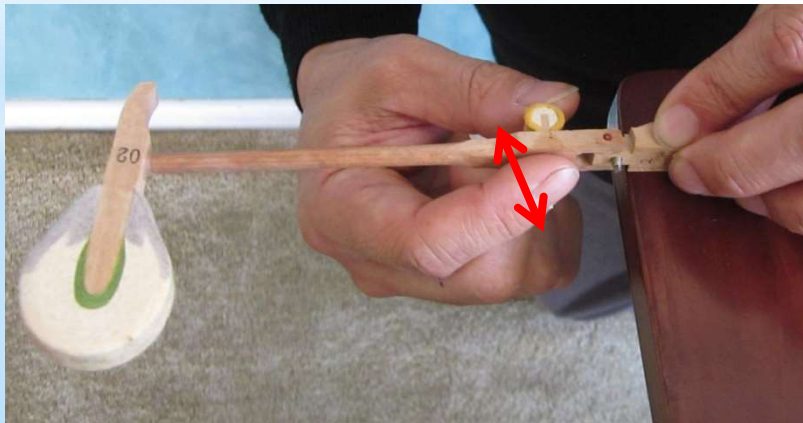


Which do you feel heavy?

Effect of Gravity



Vertical movement
The Mol + Torque by gravity

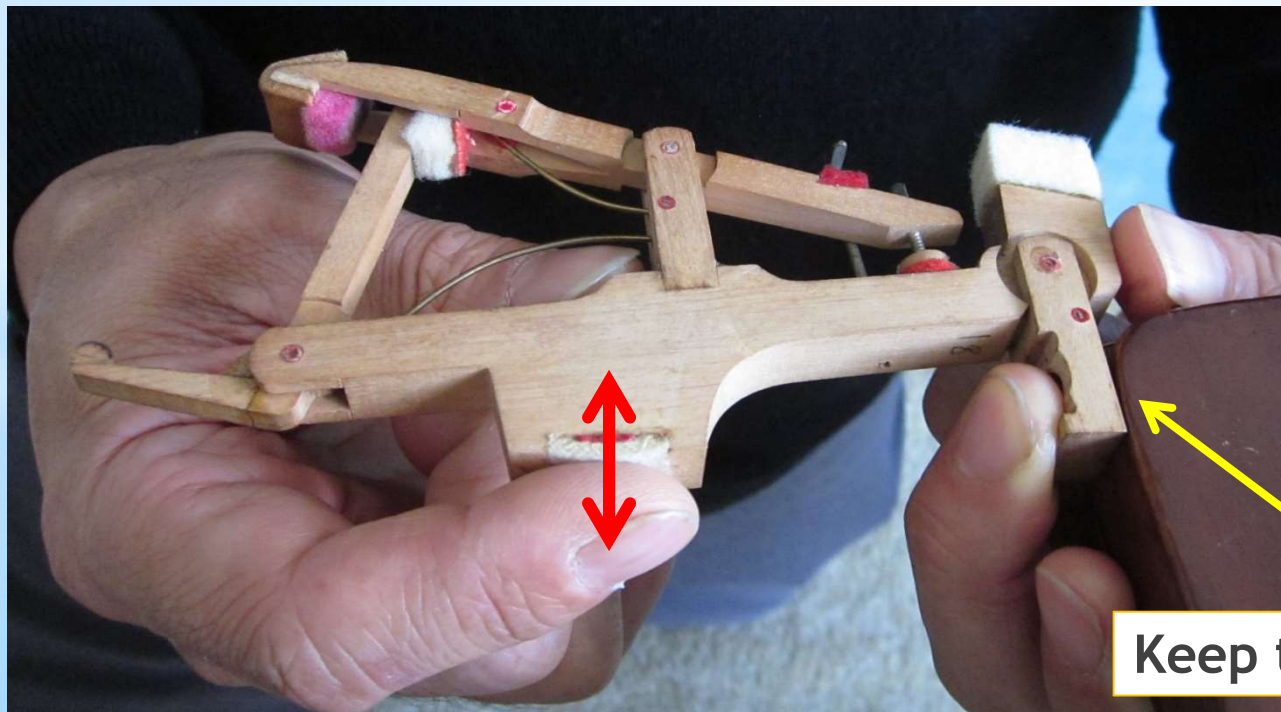


Horizontal movement
The Mol only

Experience Mol of a wippen

Kinetic resistance of the wippen = Mol of the wippen

Move the wippen forward and backward quickly at parallel to the ground



Keep the flange solidly

Moment of Inertia

- Kinetic resistance of rotating object

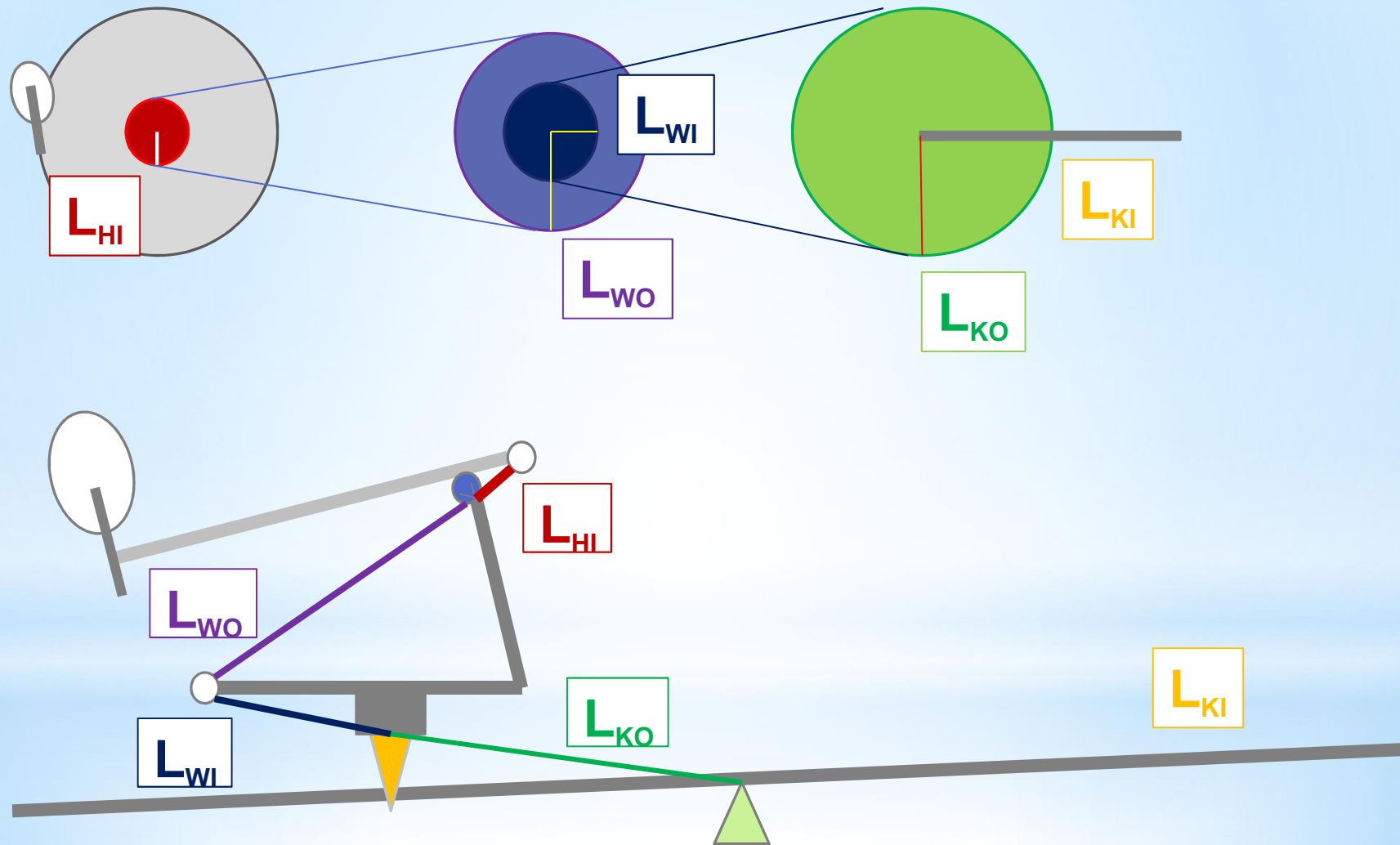
Linked Moment of Inertia

- The Moment of Inertia transferred through linked parts

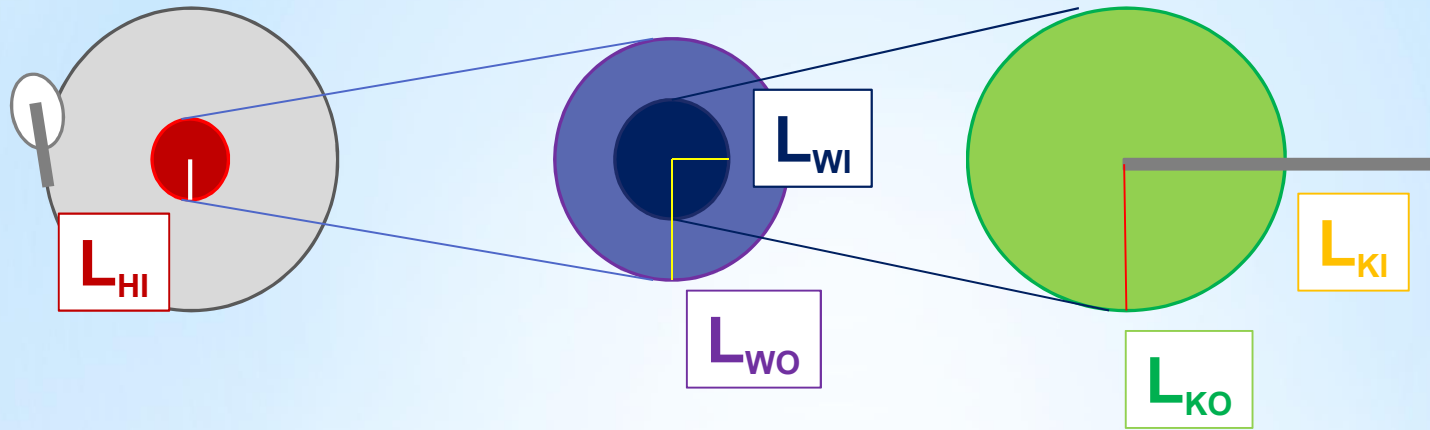
Gear Ratios

- Output/input ratio of linked rotating parts

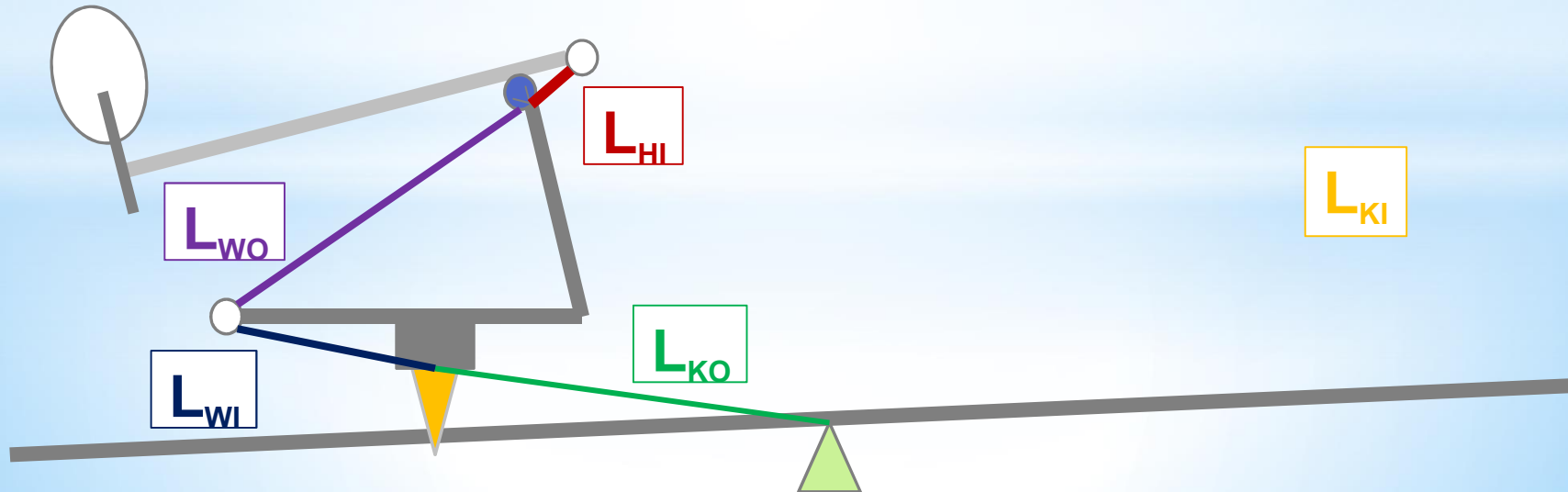
Piano action, Linked 3 rotating parts



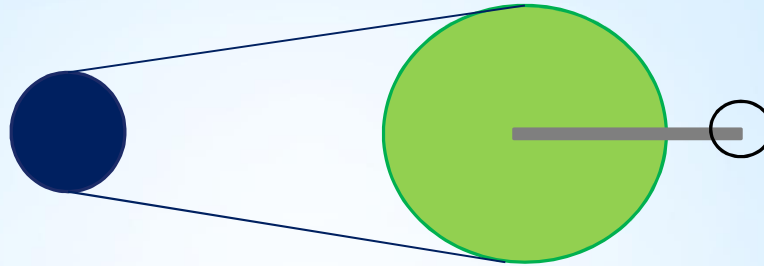
How to feel the Mol of hammer at key



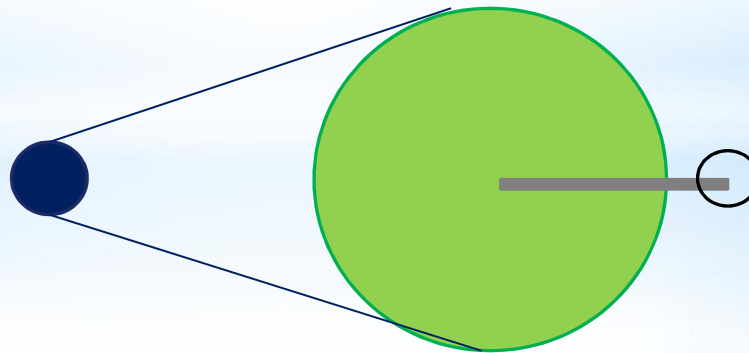
$$\text{Mol}_{(H \text{ at Key})} = \text{Mol}_{(H)} \times \left(\frac{L_{WO}}{L_{HI}} \times \frac{L_{KO}}{L_{WI}} \right)^2$$



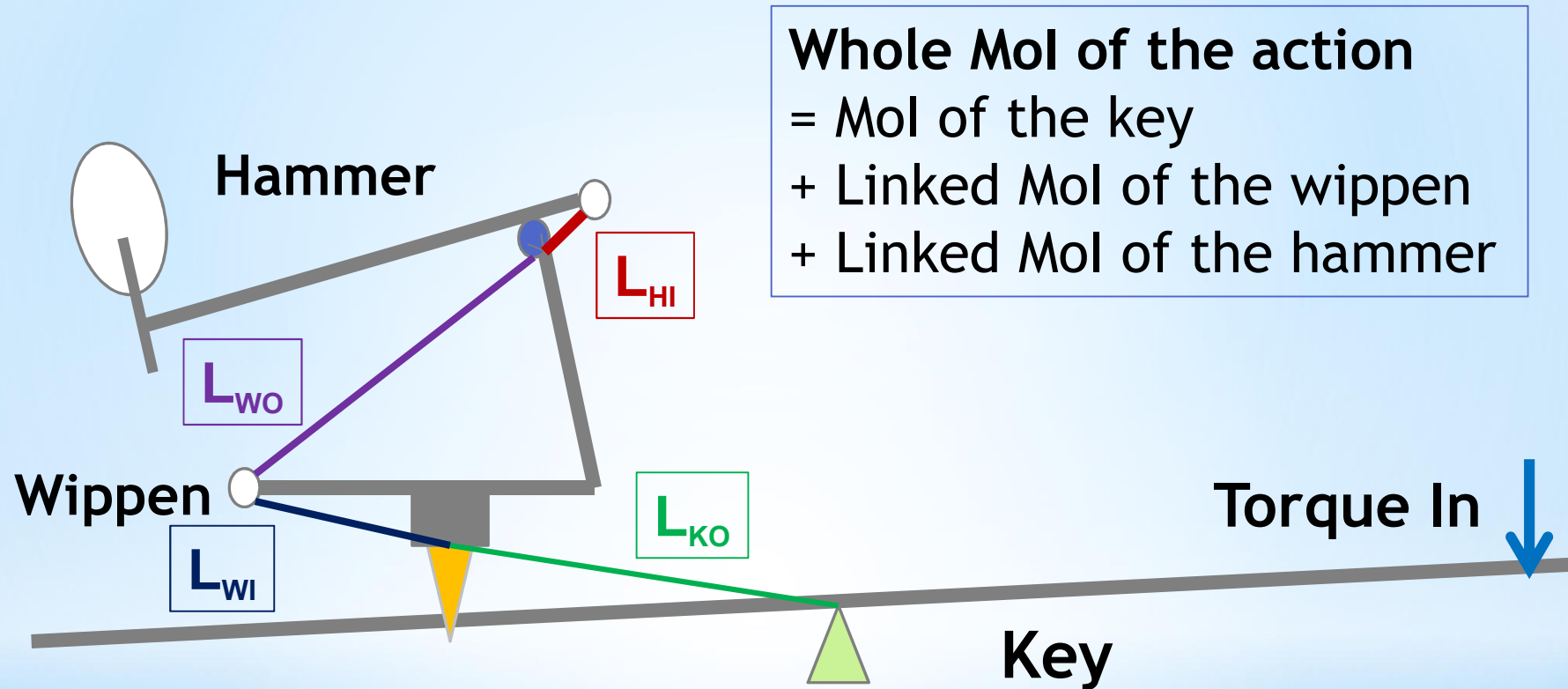
Smaller Gear Ratio = Lighter to give acceleration



Bigger Gear Ratio = Heavier to give acceleration



Linked Moment of Inertia

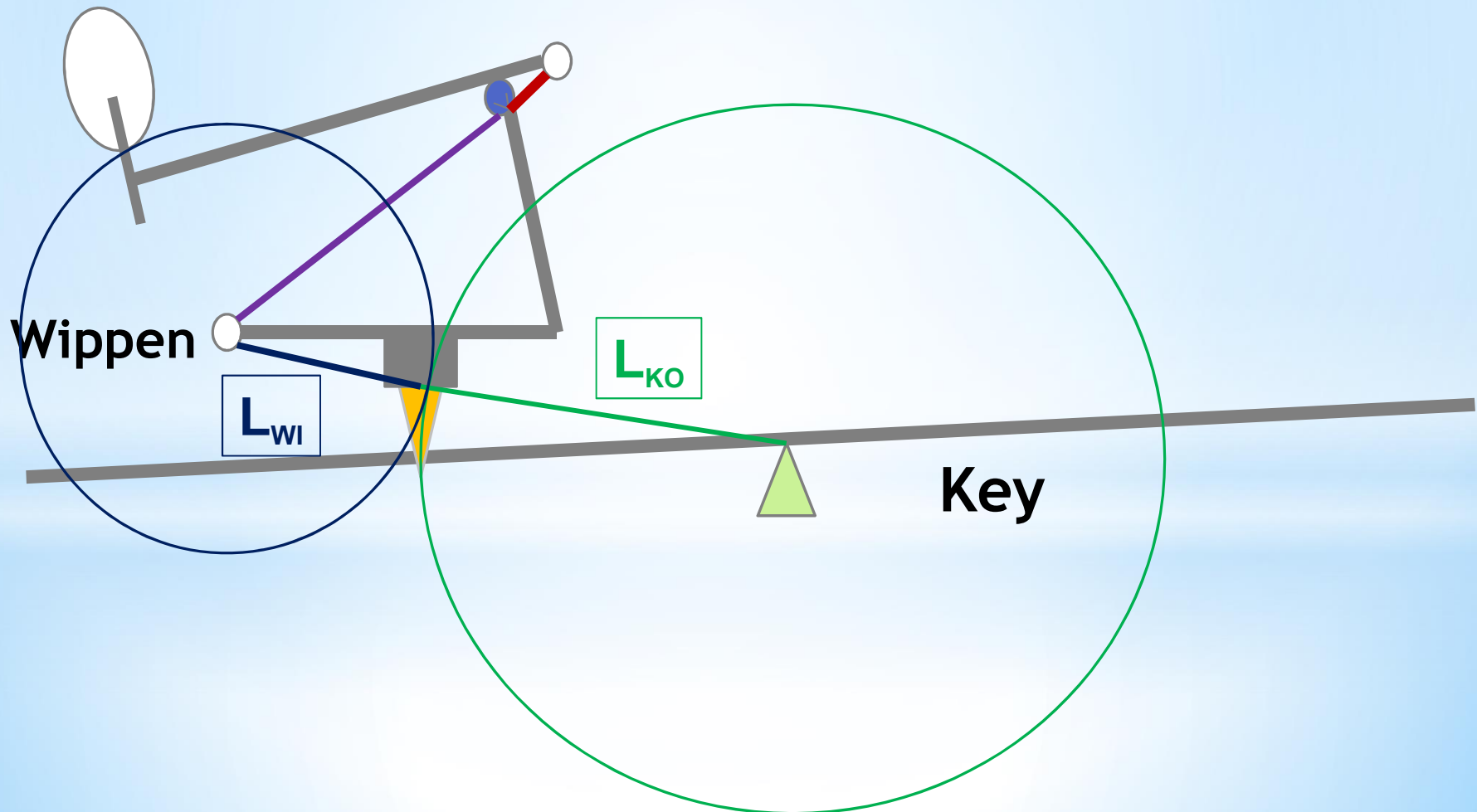


Whole Mol of the action
 = Mol of the key
 + Linked Mol of the wippen
 + Linked Mol of the hammer

$$\begin{aligned}
 \text{Mol (Whole action at key)} & \\
 &= \text{Mol}_{(K)} \\
 &+ \text{Mol}_{(W)} \times \left(\frac{L_{KO}}{L_{WI}} \right)^2 \\
 &+ \text{Mol}_{(H)} \times \left(\frac{L_{WO}}{L_{HI}} \times \frac{L_{KO}}{L_{WI}} \right)^2
 \end{aligned}$$

Big piano or Small piano?

Gear ratio (wippen - key) $\rightarrow (L_{KO} / L_{WI})^2$



Difference in $L_{(KO)}$

Sample calculation:

- Same hammer, wippen and Mol (key)
- Use each data of $L_{(KO)}$

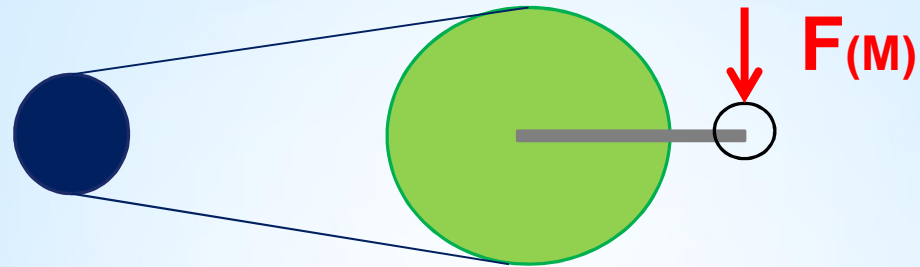
S&S model M Bottom B ($L_{KO} = 12.1$ cm)

➤ **Mol** (whole) : 202,000 g cm²

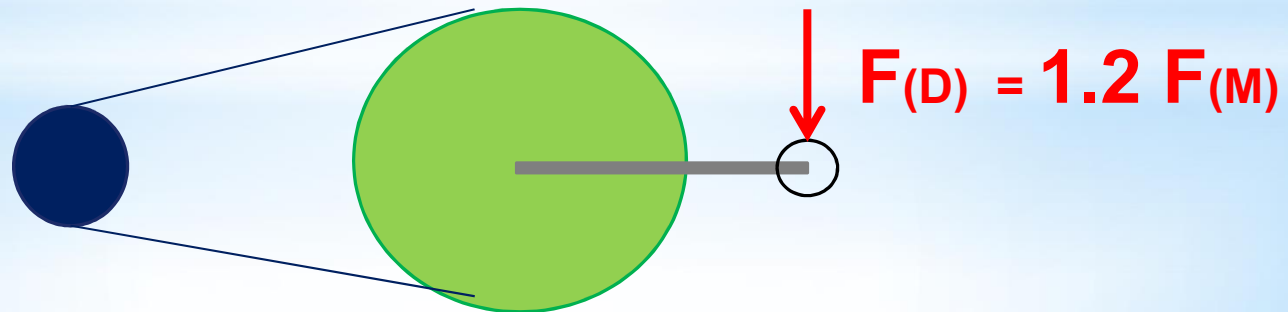
S&S model D Bottom B ($L_{KO} = 16.5$ cm)

➤ **Mol** (whole) : 316,000 g cm²

S&S M: $L_{KI} = 23.2$ cm, $L_{KO} = 12.1$ cm, $M_{ol} = 202,000$



S&S D: $L_{KI} = 31$ cm, $L_{KO} = 16.5$ cm, $M_{ol} = 316,000$



Difference in SW

Sample calculation (at S&S D) :

- Same wippen, Mol (key) and gear ratios
- Different SW

SW index #	SW grams	Mol (whole) g cm ²	Compare with #13
13	14.7	342,000	---
11	13.5	320,000	6% reduction
9	12.3	298,000	13% reduction
7	11.2	278,000	19% reduction

Relation between playing force and Mol

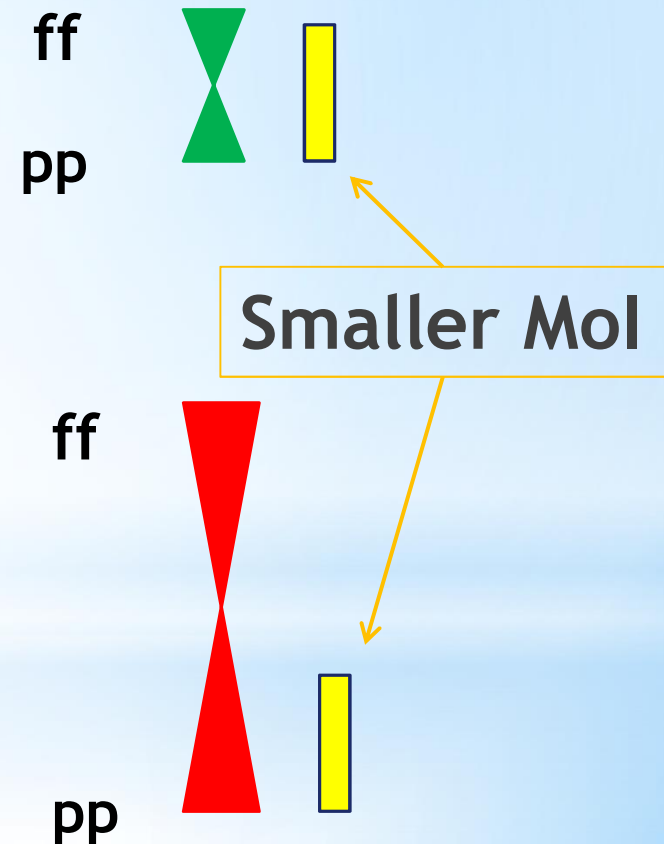
Play at lighter action with smaller Mol

The pianist who has narrow band of playing force:

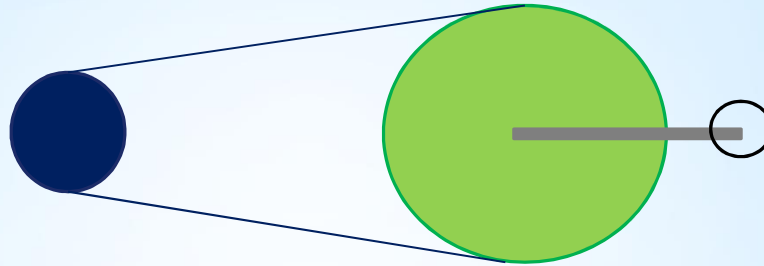
Feels controllable and expressive

The pianist who has wider band of playing force:

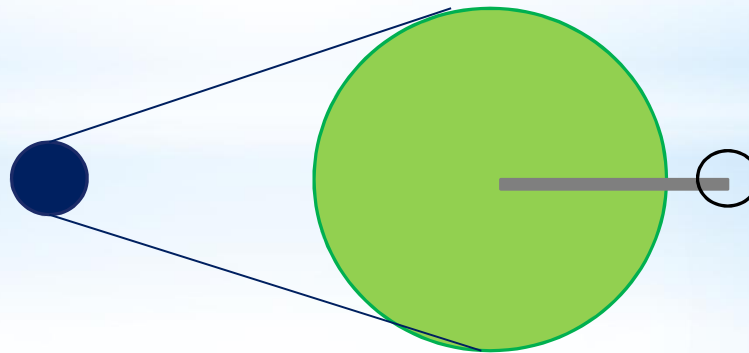
Feels limited volume and expression



Smaller Gear Ratio = Lighter to give acceleration



Bigger Gear Ratio = Heavier to give acceleration

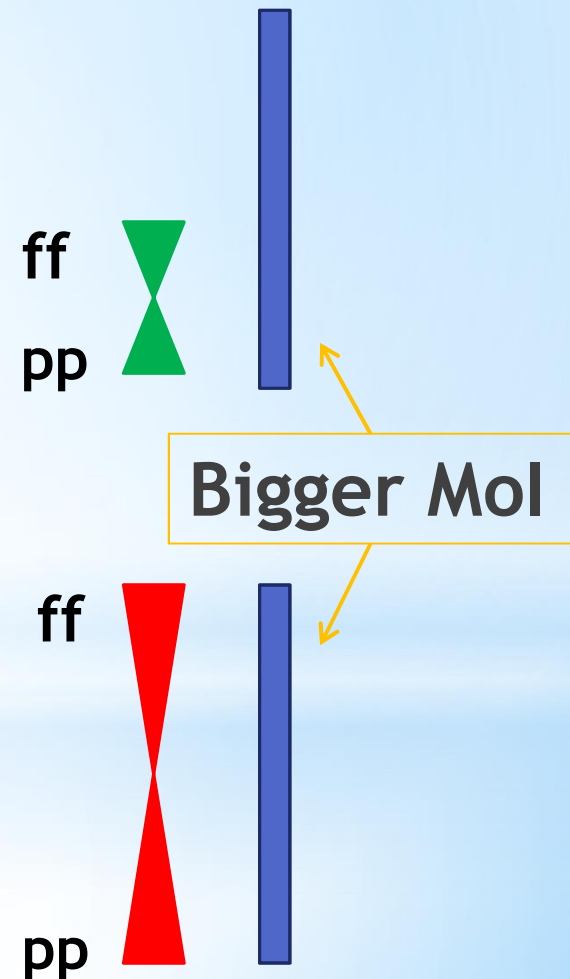


Relation between playing force and Mol

Play at heavier action with bigger Mol

The pianist who has narrow band of playing force:

Feels too heavy



The pianist who has wider band of playing force:

Feels controllable and expressive

Hints for setting up with Mol consideration

- Strike Weight
- Ratios
- Location of key leads

Decide **Strike Weight** level

- Lighter hammer has better tremolo ability
- Heavier hammer has deeper and bigger tone

➔ Find desired SW with

- Preferred Strike Ratio
- Desired touchweight
- Tonal quality

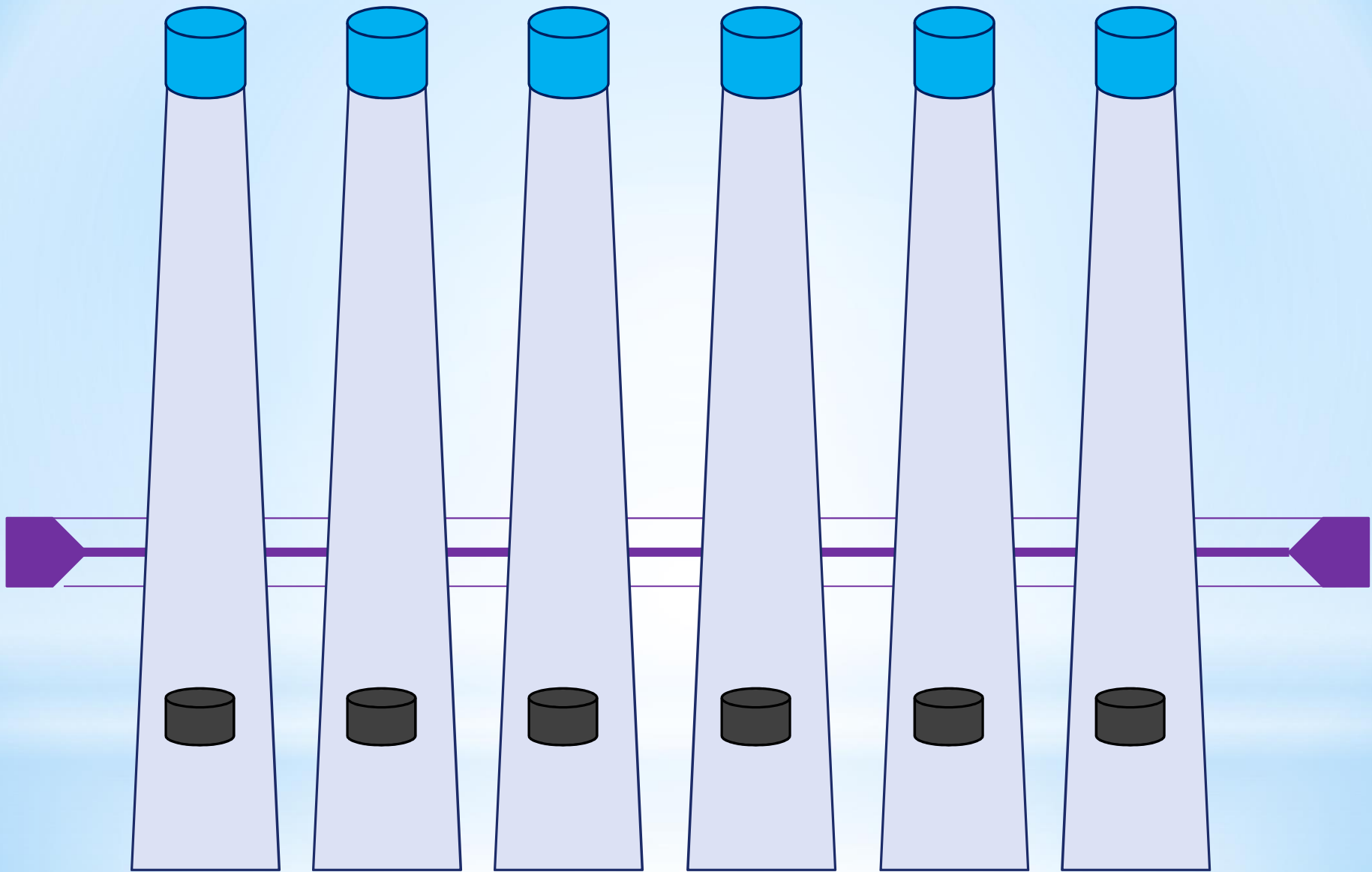
Set Ratios

- **Action Ratio** for standard regulation
- **Strike Ratio** for reasonable static touchweight
- **Gear ratios** are related with AR & SR

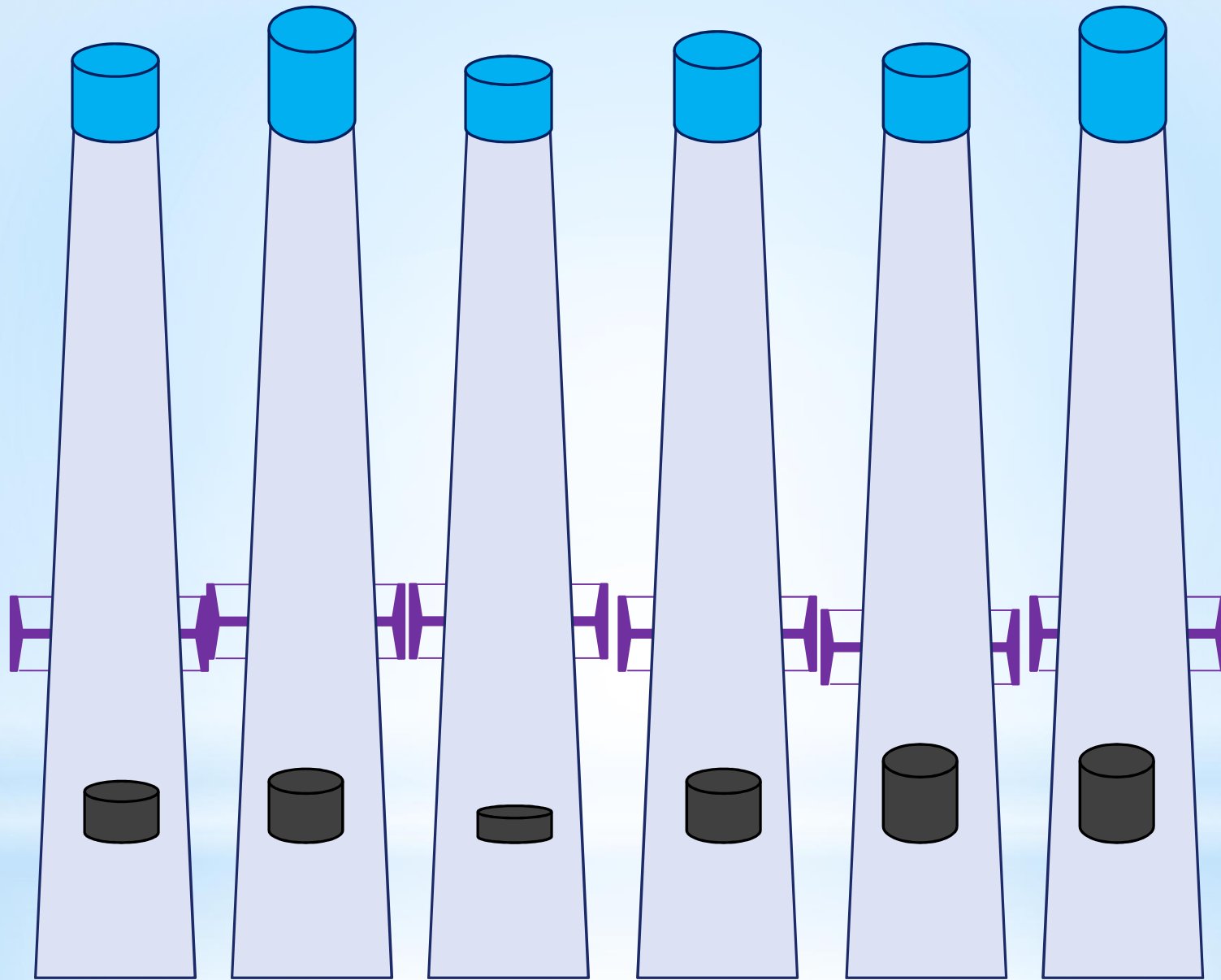
Location of key leads

Locate key leads according to the amount of Mol

FW would set at least minus 3 grams from FW ceiling (suggested by David Stanwood)



Even SW, FW, BW, then Mol are even



Same BW, but the Mol and R is different

Sample set up (1)

**Small ~ moderate grand with existing parts:
Requested lighter touch & good repetition**

- ❖ Adjust SW **lighter**
- ❖ Lower SR to **5.5 ~ 6.0**
- ❖ FW is set at least **minus 3 grams** from **ceiling**
- ❖ Relocate key leads **towards balance pin**
- ❖ Adjust BW to **36 ~ 38 grams**

Sample set up (2)

**Small ~ moderate grand with existing parts:
Requested heavier touch & keep good repetition**

- ❖ Adjust SW **lighter**
- ❖ Higher SR to **6.0 ~ 6.5**
- ❖ FW is set at least **minus 3 grams** from **ceiling**
- ❖ Relocate key leads to **outer side**
- ❖ Add key lead into **back side**
- ❖ Adjust BW to **40 ~ 45 grams**

Sample set up (3)

**Concert grand:
Standard touch and good repetition ability**

- ❖ Smooth SW around #9 ~ #10
- ❖ 5.5 ~ 6.0 of Strike ratio
- ❖ Set FW minus 3 grams from ceiling
- ❖ Locate key leads to inner side
- ❖ 40 g ~ 42 g of BW

or tapered BW (45 g :lower bass, 42g: upper bass, 40 g: tenor and 38 g: treble etc.)