PHY 117 HS2024

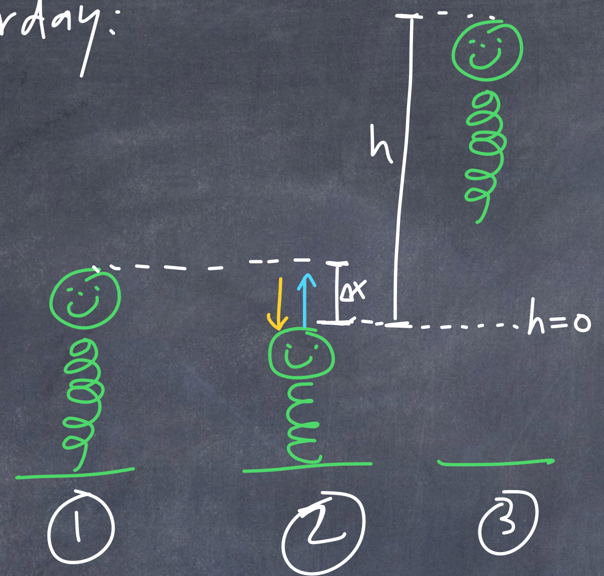
Today:
Energy transformation / conservation
Non-conservative forces
Elastic and inelastic collisions
Momentum conservation
Relationship of momentum and force
Impulse = change in momentum

Quiz #2:
OLAT -> Quizzes -> Quiz 2
100/690 participants.
Average time: 9 minutes.
Please participate !

Note:
K: kinetic energy
units: N.m
k: spring constant
units: $\frac{N}{m}$
Today I write
K for kinetic energy

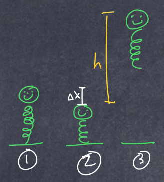
Week 3, Lecture 2
Oct. 2nd, 2024
Prof. Ben Kilminster

Yesterday:



we found work for me to compress the spring is $W_{me} = +\frac{1}{2}k(\Delta x)^2$

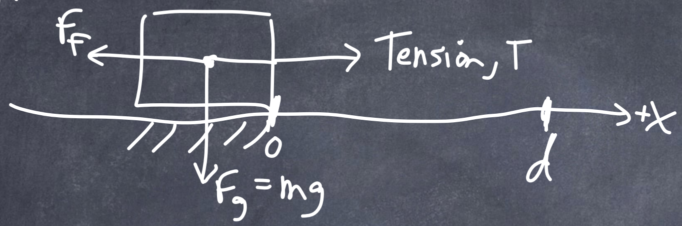
work done by spring is $W_{spring} = -\frac{1}{2}k(\Delta x)^2$

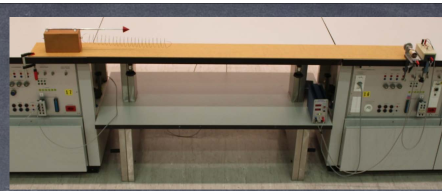

h
Δx
1
2
3

Non-conservative force:

f_F is opposite movement

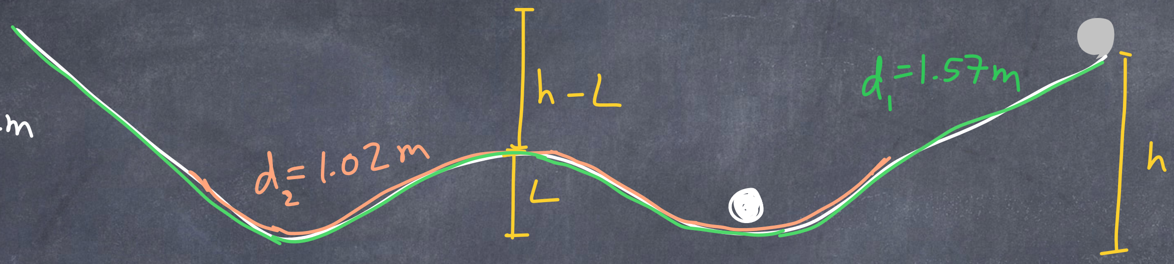
(−)

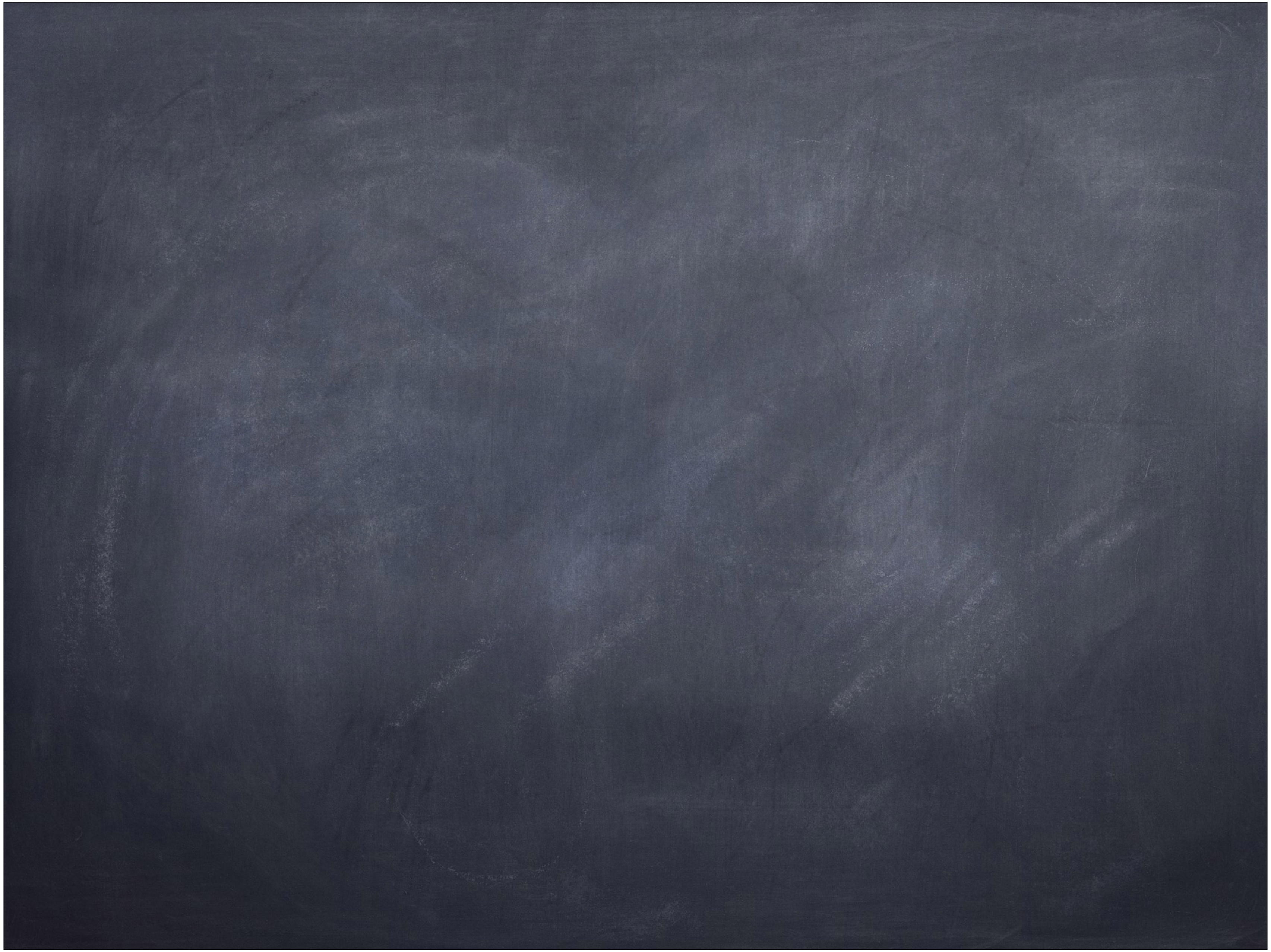




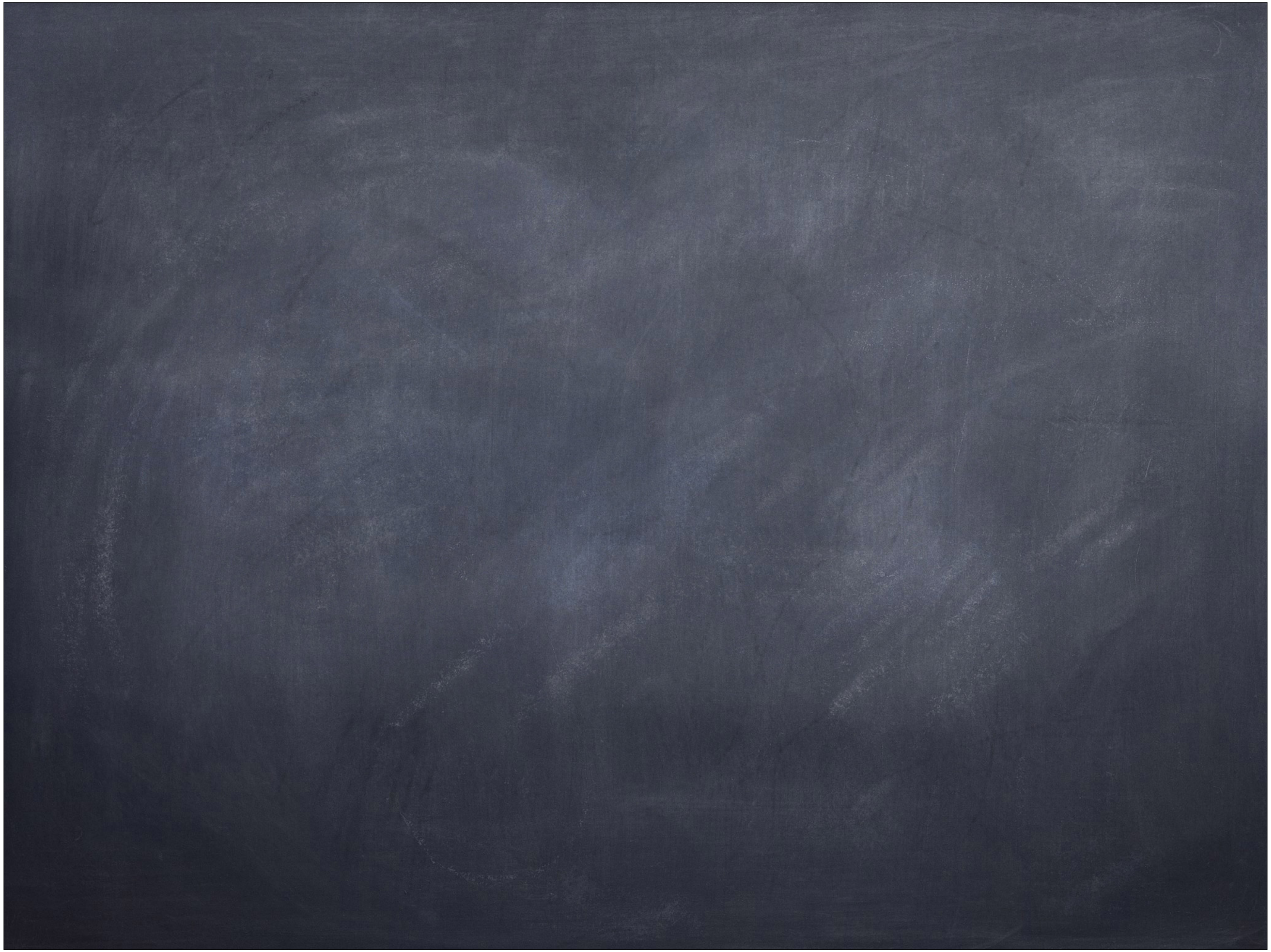
How many times will a steel ball roll across this track before getting stuck?

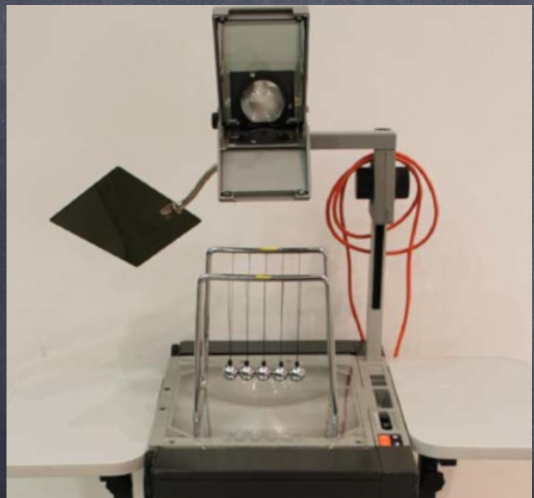
$h - L = 6\text{cm}$



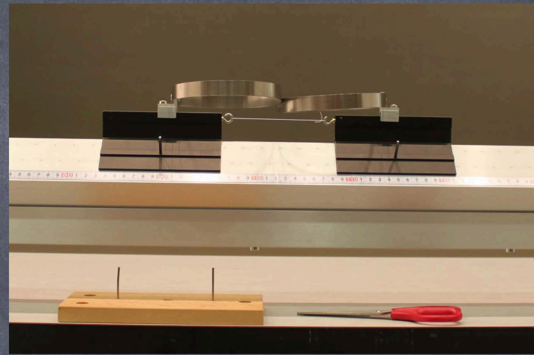



Titan
Amorphes Metall
Rostf. Stahl

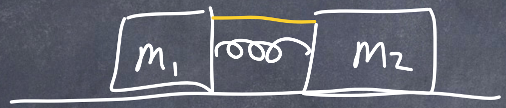




Other momentum conservation examples:

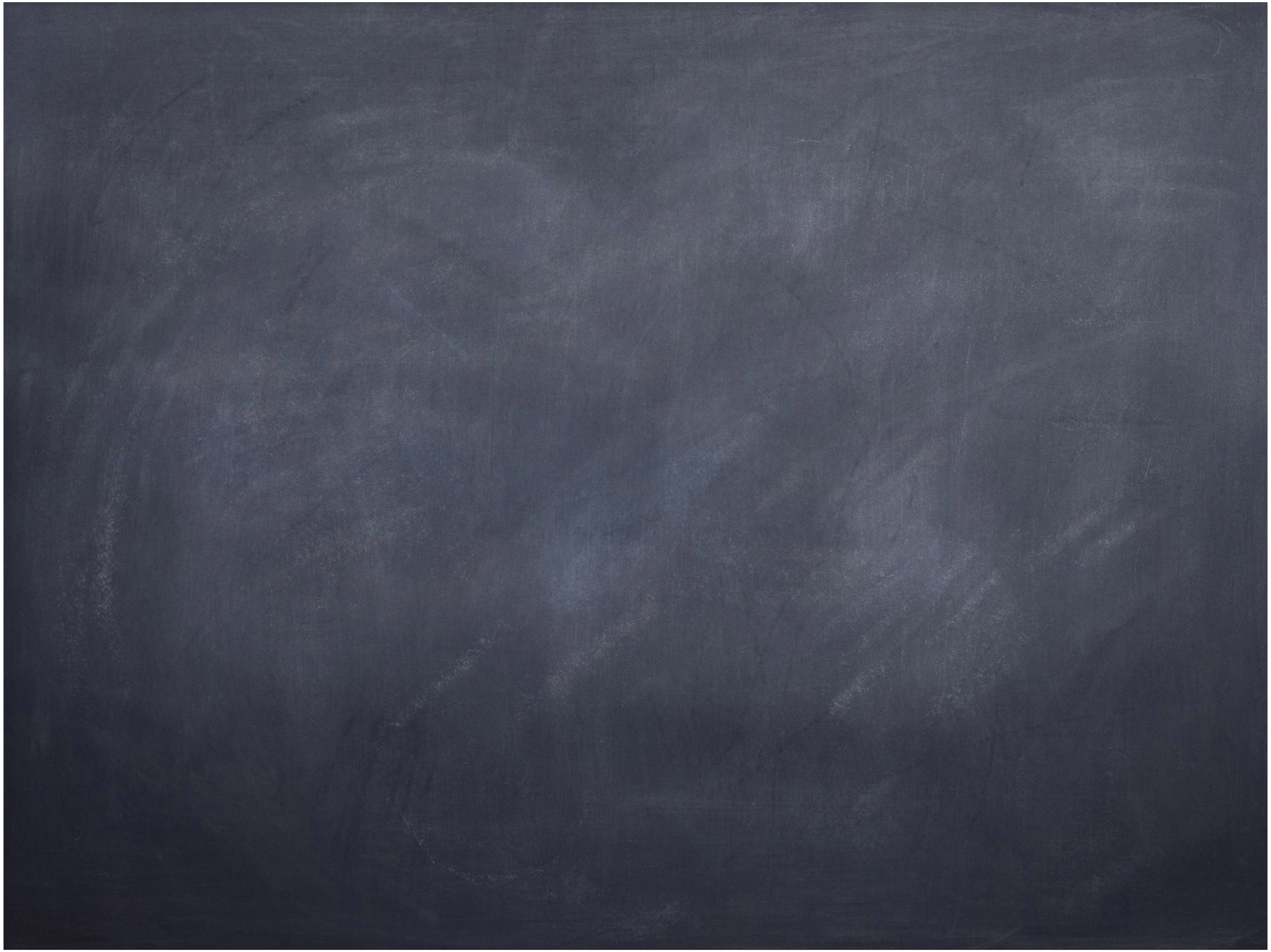


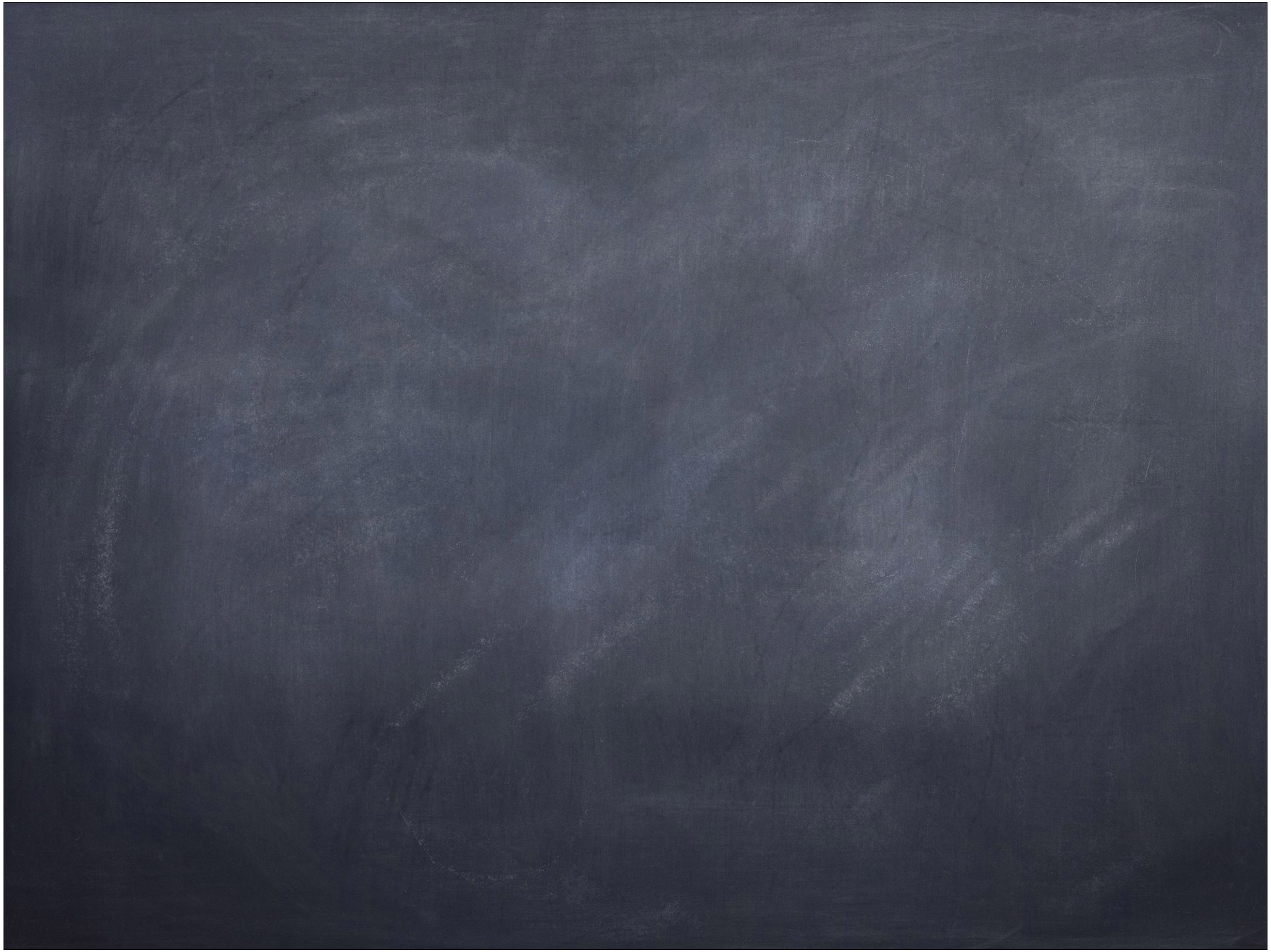
①

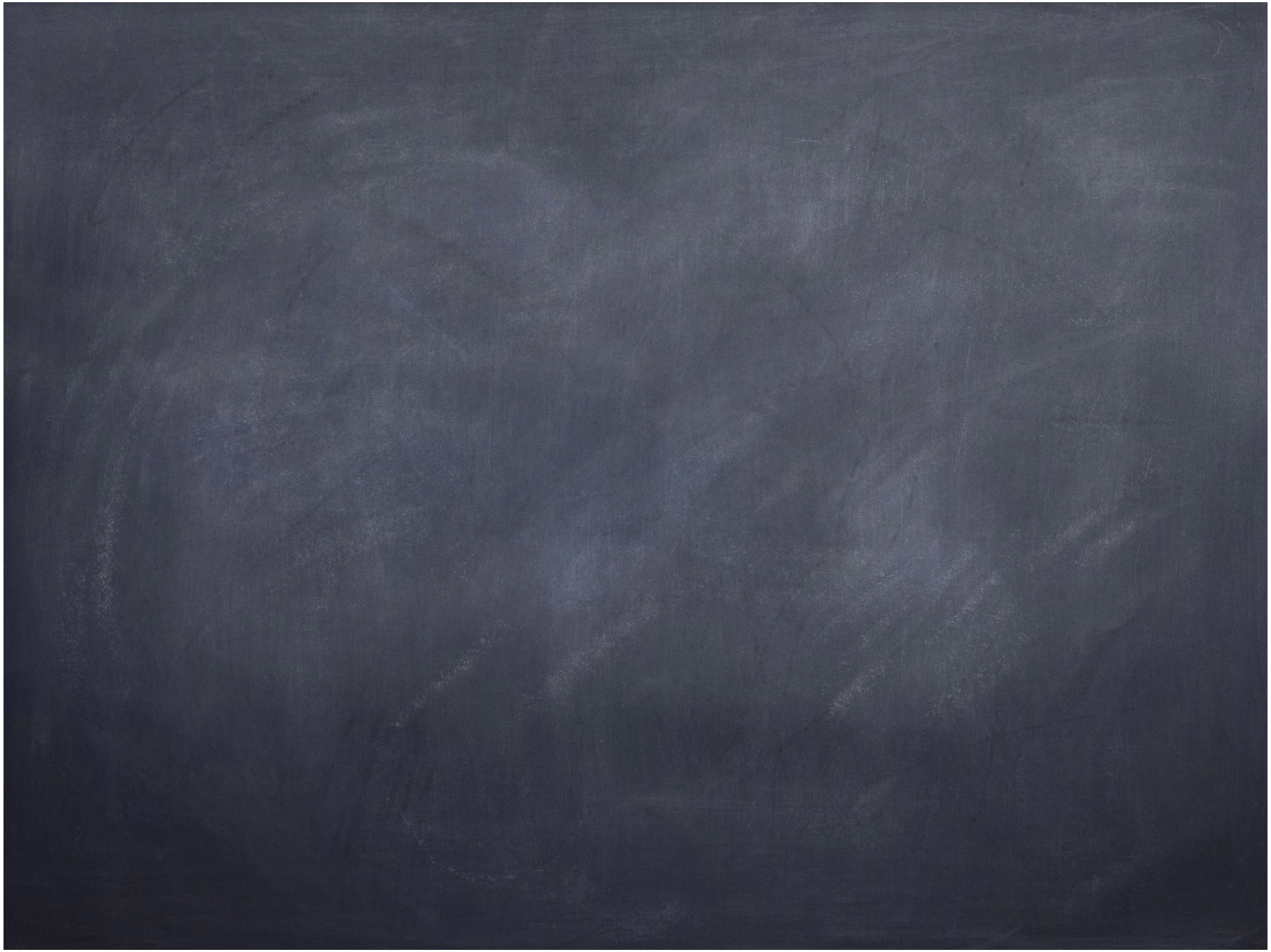


②

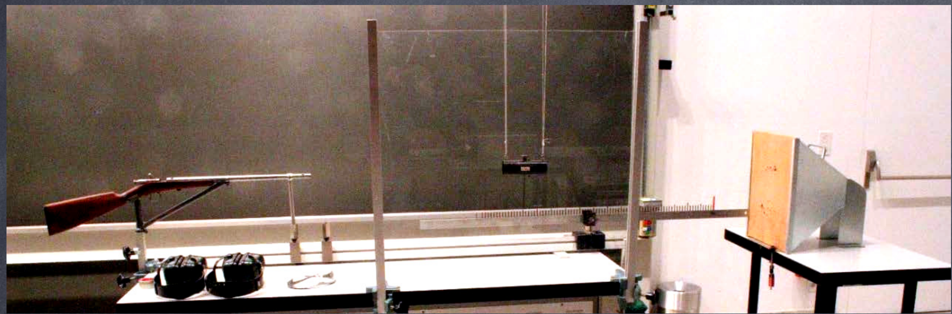
$m_2 > m_1$

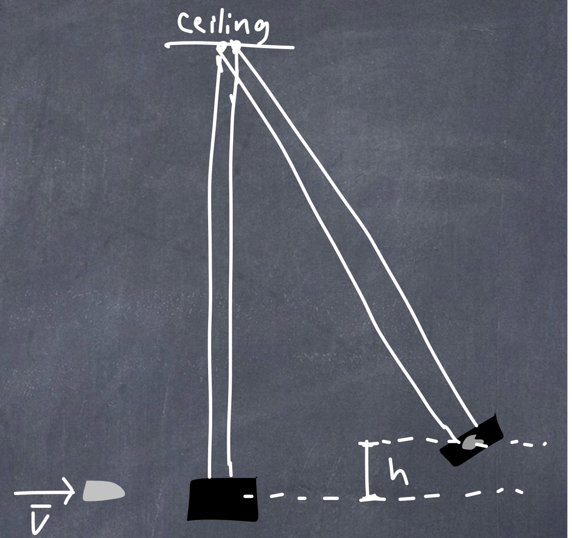






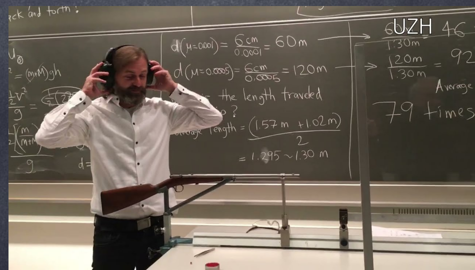
Ballistic pendulum experiment





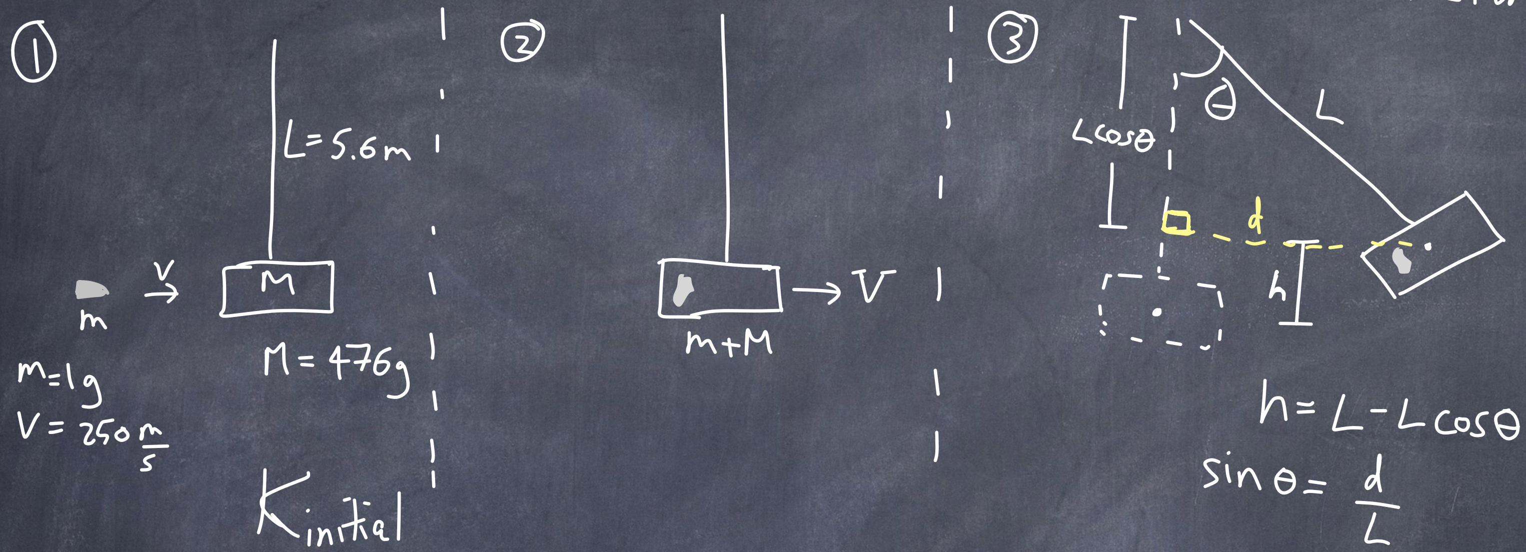
How high will the block go?

video posted



https://www.youtube.com/watch?v=v2s6Nxc6Dr8

Ballistic Pendulum – Momentum conservation in inelastic collision.



Between ① + ②, momentum is conserved. Kinetic energy is not conserved. **Inelastic collision**

$mv = (m+M)V$ V: velocity of block + bullet.

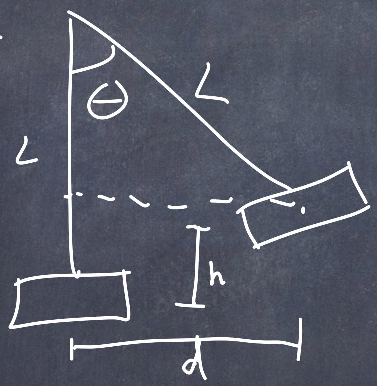
Between ② + ③, this is elastic.

$K_{②} = U_{③}$

$$\underbrace{\frac{1}{2}(\cancel{m+M})V^2}_{K_{2}} = \underbrace{(\cancel{m+M})gh}_{U_{3}}$$

solve for $h = \dfrac{\frac{1}{2}V^2}{g} = \dfrac{\frac{1}{2}\left[\frac{m}{m+M}v\right]^2}{g} =$ $\boxed{\text{predicted } h \quad 0.014\,m}$

$L = 5.6\,m$



we measure d.

$h = L - L\cos\theta$

$\sin\theta = \dfrac{d}{L} \Rightarrow \theta = \sin^{-1}\left(\dfrac{d}{L}\right)$

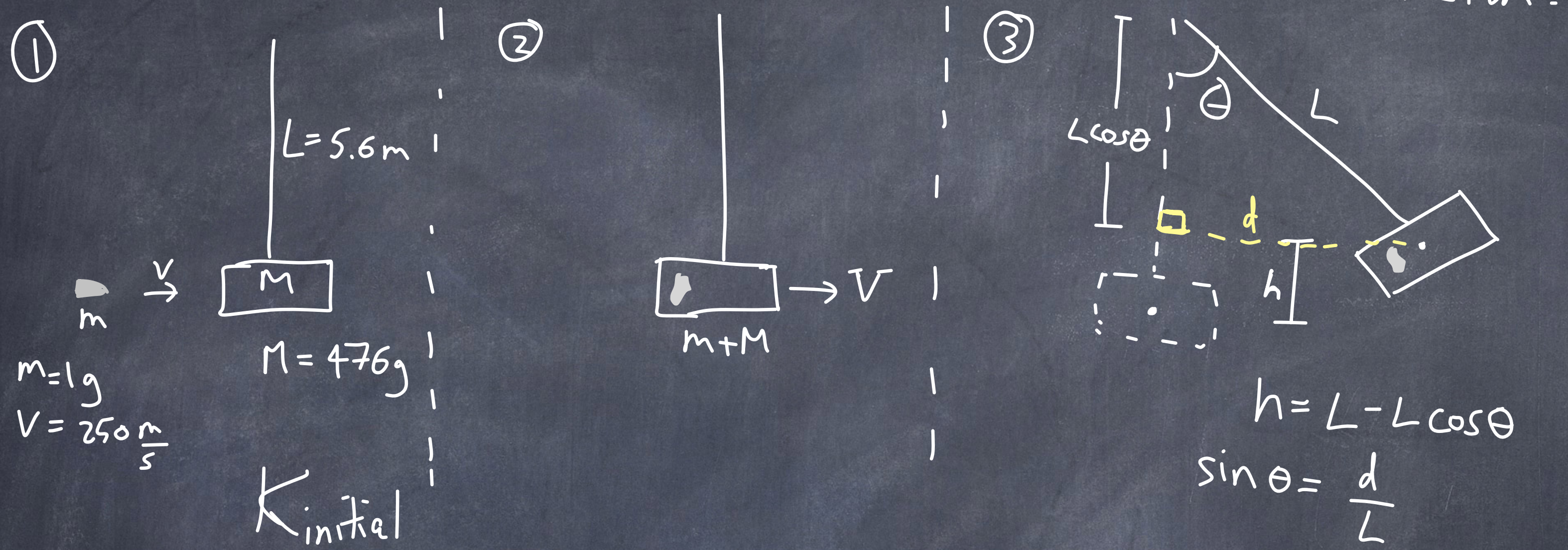
we can measure d, figure out θ, then figure out h.

measure $d = 0.4\,m$, $\theta = \sin^{-1}\left(\dfrac{0.4\,m}{5.6\,m}\right) = 0.07$ radians

and calculate $h = L - L\cos(0.07\text{ rad}) = 5.6\,m - 5.585$

$\boxed{\text{measured } h = 0.014\,m}$

Ballistic Pendulum – Momentum conservation in inelastic collision.



Note:

If kinetic energy was conserved, then

$$K_{1} = U_{3}$$

$$\frac{1}{2}mv^2 = mgh \longrightarrow h = \frac{v^2}{2g}$$

$$\underline{\underline{h = 6.7\,m}}$$

wrong!

(collision is inelastic)

Questions from students:

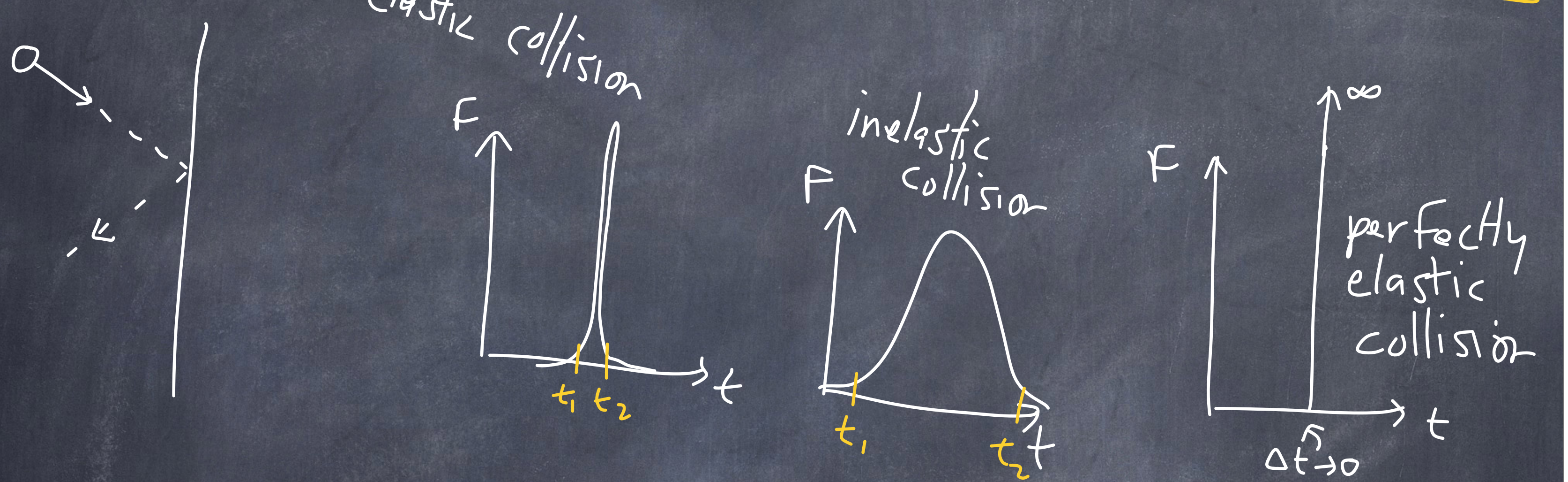
1) what is the difference between elastic & inelastic collisions in terms of F vs. t?

2) If momentum changes directions, wouldn't the average force always be the same?

3) How can something change directions? Isn't momentum not conserved if this happens?

4) What if the problem is 2-dimensional? How is momentum conserved?

1) what is the difference between elastic & inelastic collisions in terms of F vs. t ?



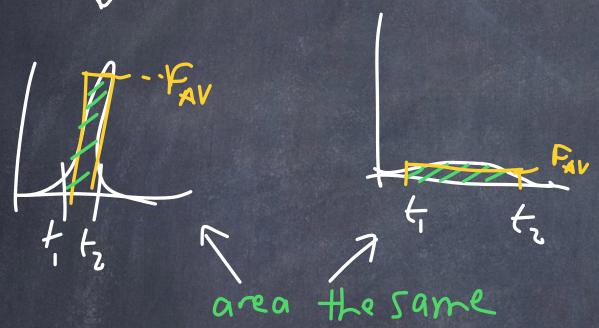
For perfectly elastic collisions,
$\Delta t \to 0$, $F \to \infty$
(these don't happen in the real world.
All interactions have some Δt)

$$\Delta p = I = F_{AV}\,\Delta t$$

2) If momentum changes directions, isn't F_{AV} always the same?

The average force depends on Δt.

either

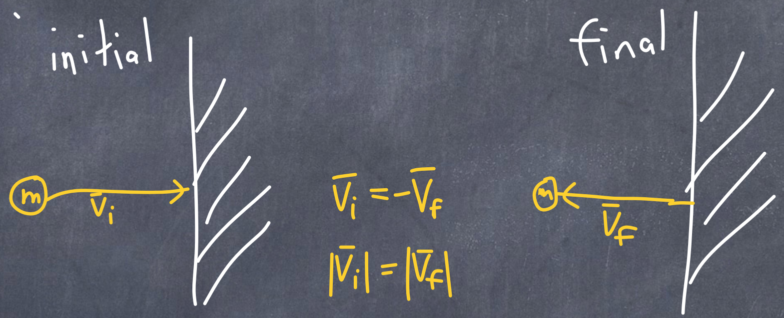


Notice, we can have the same $\Delta p = p_2 - p_1$ in cases where Δt is small and F_{AV} is large, or when Δt is large and F_{AV} is small.

In both cases Δp is the same (area is the same)

How can something change directions? Isn't momentum not conserved if this happens?

Consider this case:



The momentum changes from mV_i to mV_f

$$\bar{P}_f = -\bar{P}_i \quad (1)$$

substitute in (1)

what happened?

$$\Delta \bar{p} = \bar{P}_2 - \bar{P}_1 = P_f - P_i = -\bar{P}_i - \bar{P}_i = -2\bar{P}_i$$

The momentum changed.

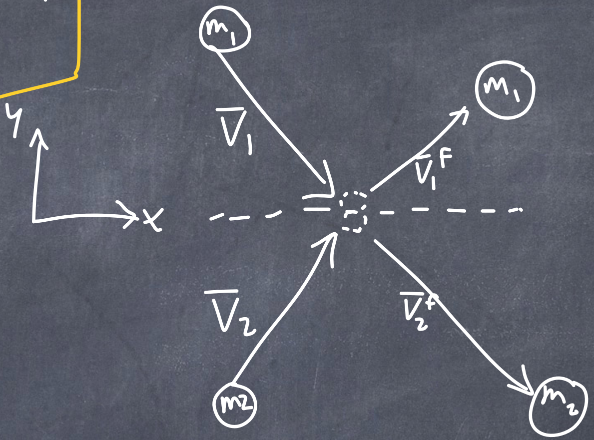
How? The wall provides a force F_{AV} for a time Δt

$$\Delta p = F_{AV}\Delta t \implies \bar{F}_{AV} = \frac{-2\bar{P}_i}{\Delta t}$$

If we know Δt, we can calculate F_{AV}

④ What if the problem is 2-dimensional?
How is momentum conserved?

consider this inelastic collision



Momentum will be conserved in all directions:

Therefore, $\Sigma \bar{p}_i = \Sigma \bar{p}_f$ we have these equations.

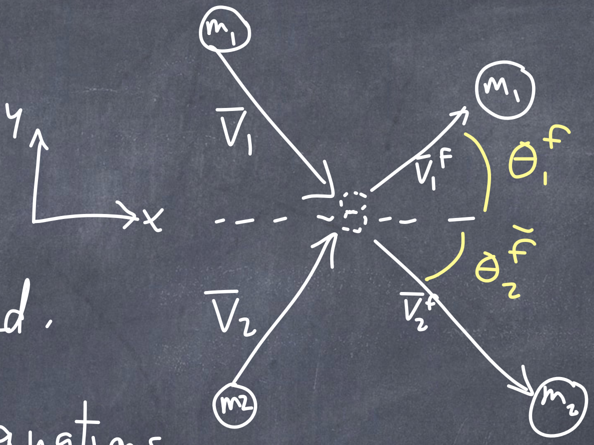
$$\Sigma p_{x_i} = \Sigma p_{x_f} \longrightarrow \begin{cases} m_1 v_{1_x} + m_2 v_{2_x} = m_1 v_{1_x}^f + m_2 v_{2_x}^f \\ \\ m_1 v_{1_y} + m_2 v_{2_y} = m_1 v_{1_y}^f + m_2 v_{2_y}^f \end{cases}$$

$$\Sigma p_{y_i} = \Sigma p_{y_f}$$

If we know the masses and initial velocities, we would have 4 unknowns and 2 equations.
So we need more information to solve this.

④ Continued...

If the collision in 2D were also elastic, then K would be conserved.



Then we would have 3 equations and 4 unknowns:

Kinetic energy conservation: $\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 = \frac{1}{2}m_1{v_1^f}^2 + \frac{1}{2}m_2{v_2^f}^2$

momentum conservation in x: $m_1v_{1_x} + m_2v_{2_x} = m_1v_{1x}^f + m_2v_{2x}^f$

momentum conservation in y: $m_1v_{1_y} + m_2v_{2_y} = m_1v_{1y}^f + m_2v_{2y}^f$

Knowing one of the angles, θ_1^f or θ_2^f, or one final velocity component ($v_{1x}^f, v_{2x}^f, v_{1y}^f, v_{2y}^f$) would be enough information to solve the problem.