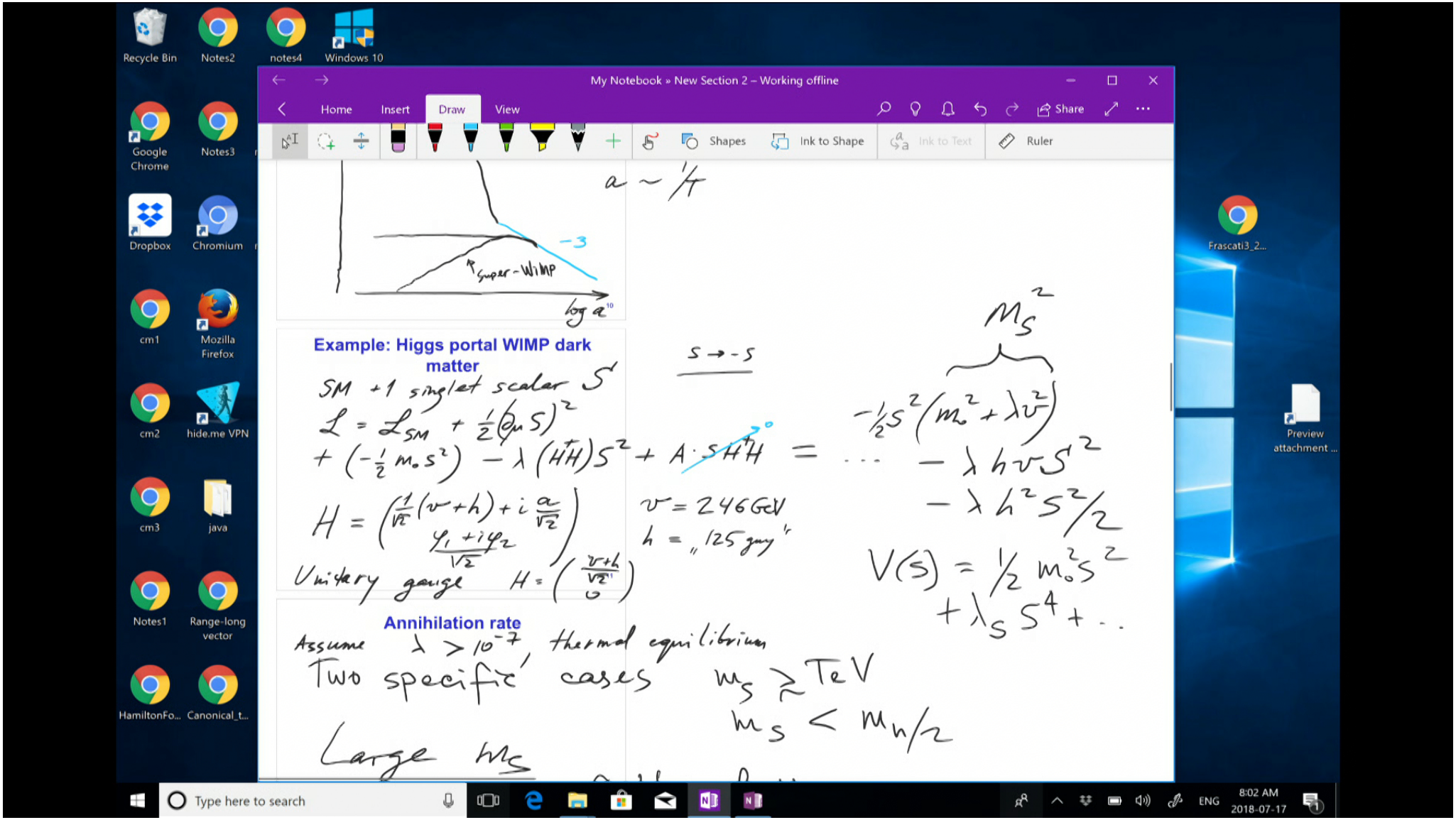
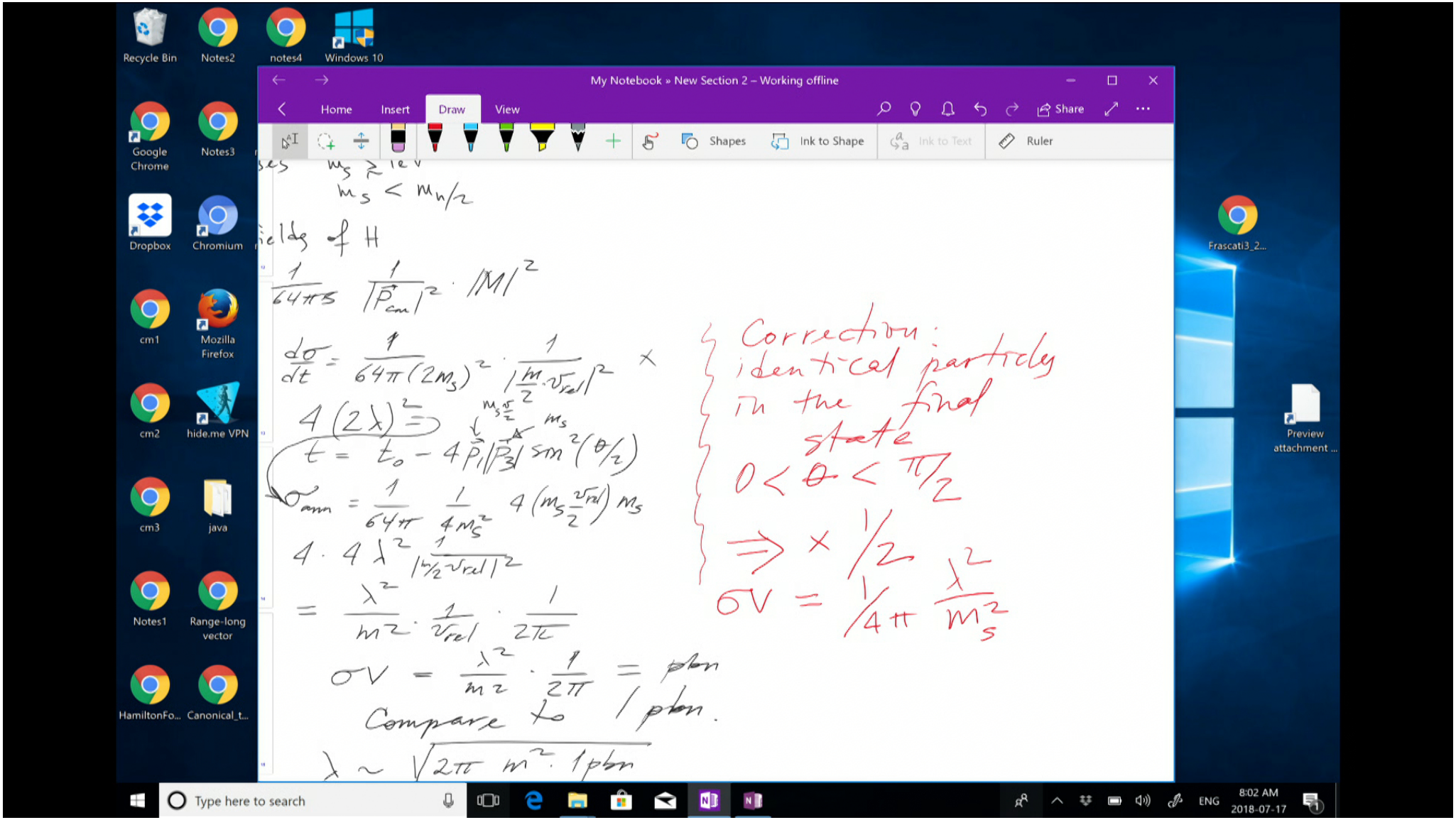
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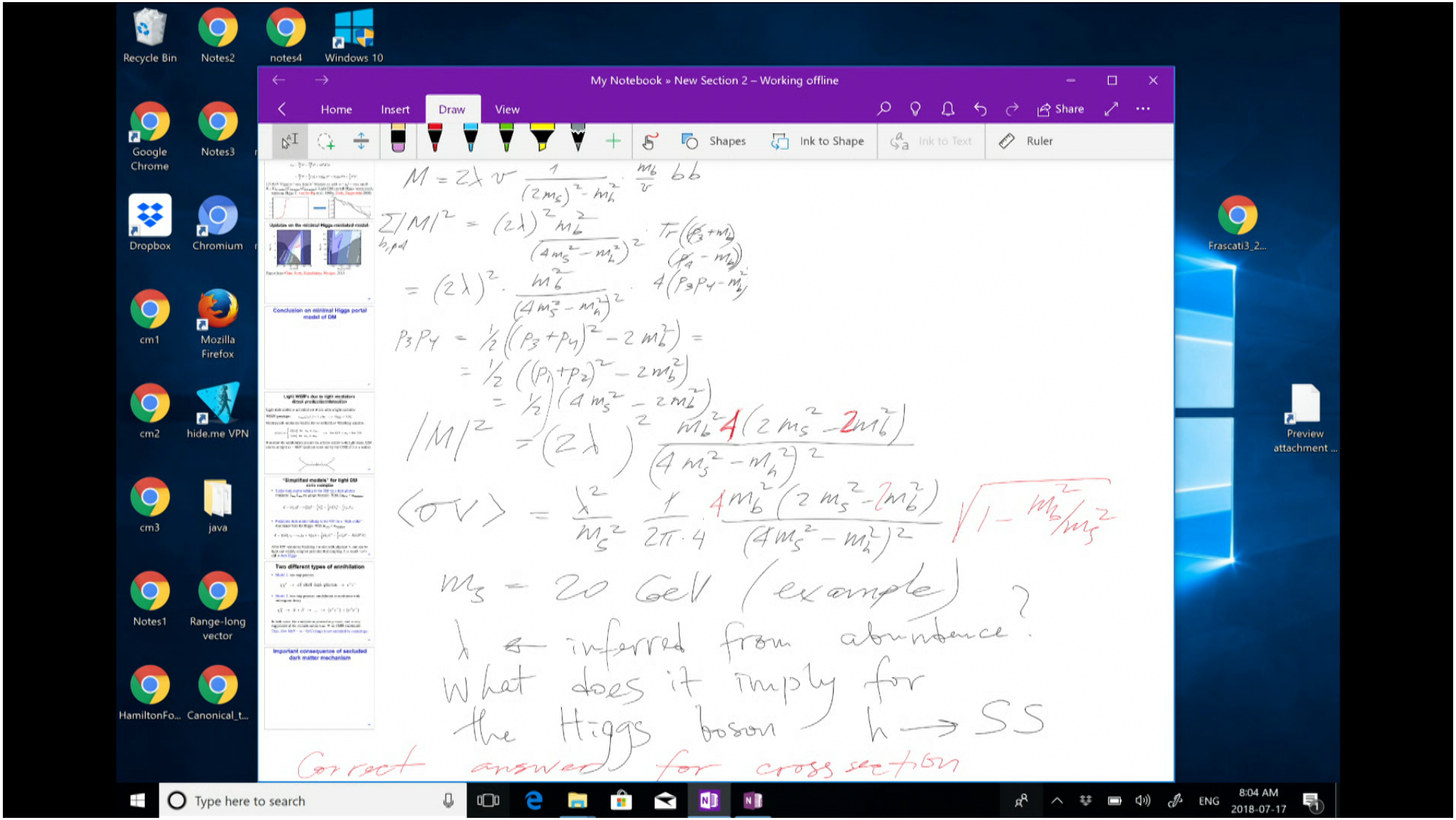
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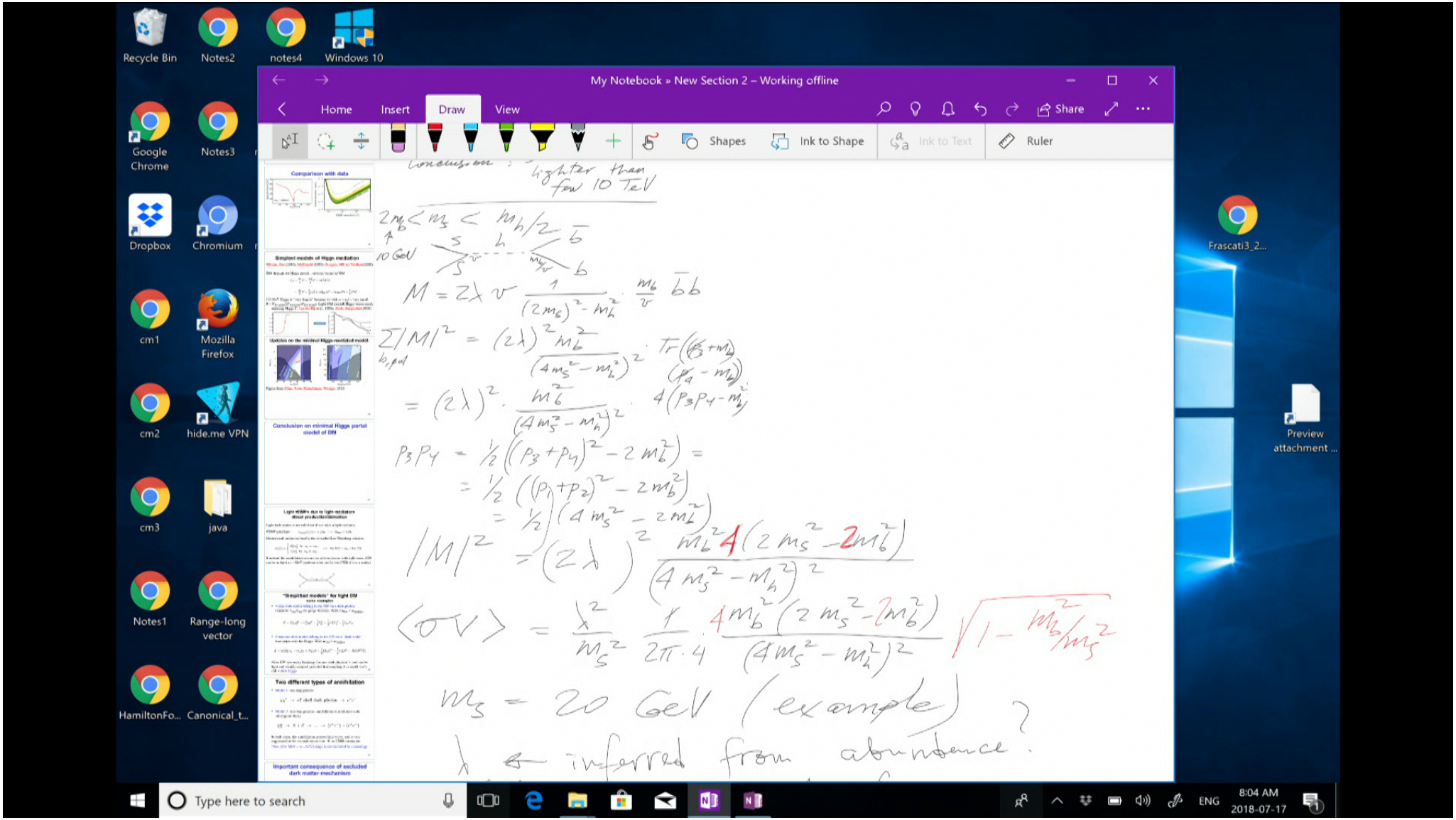
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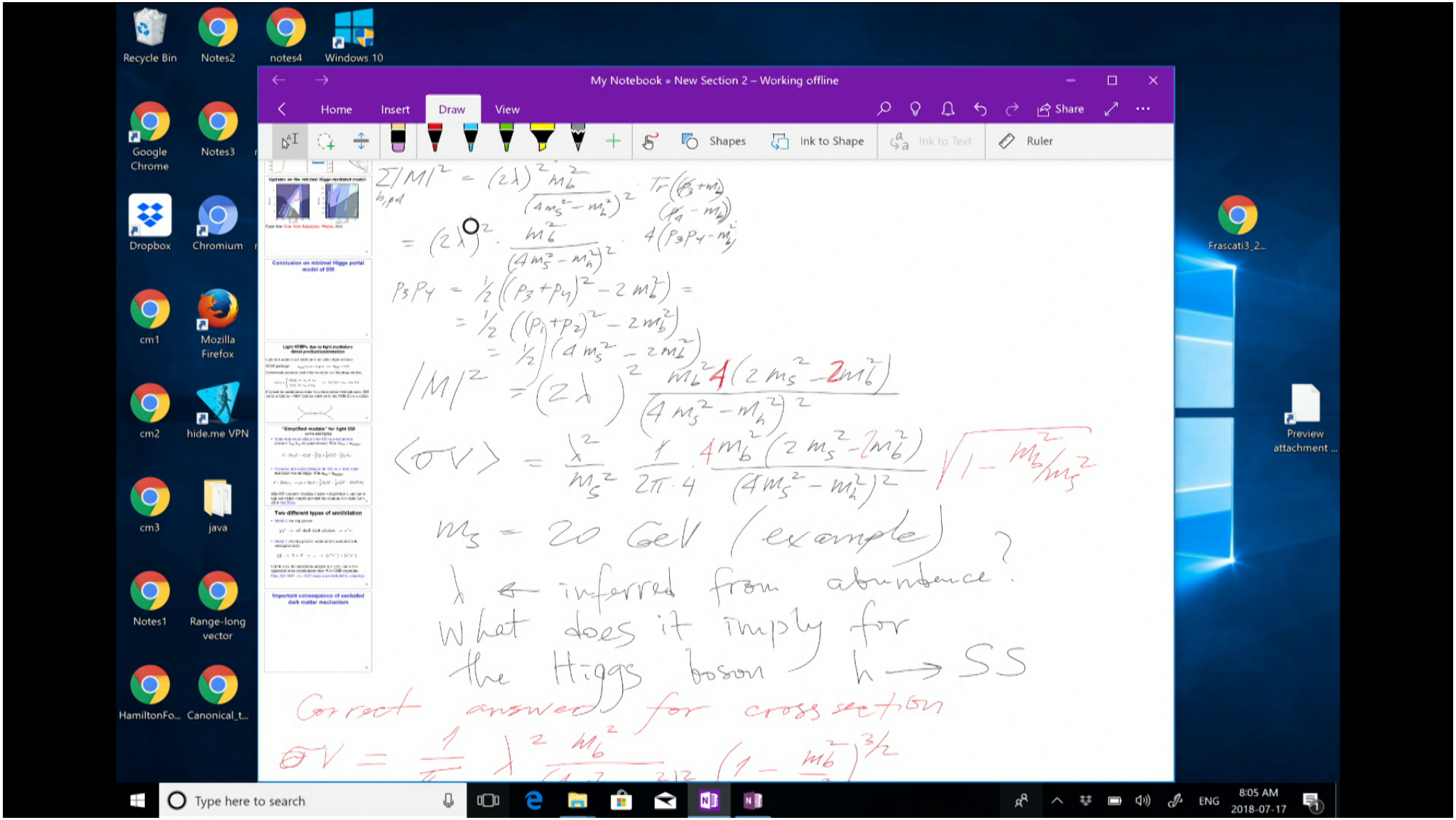
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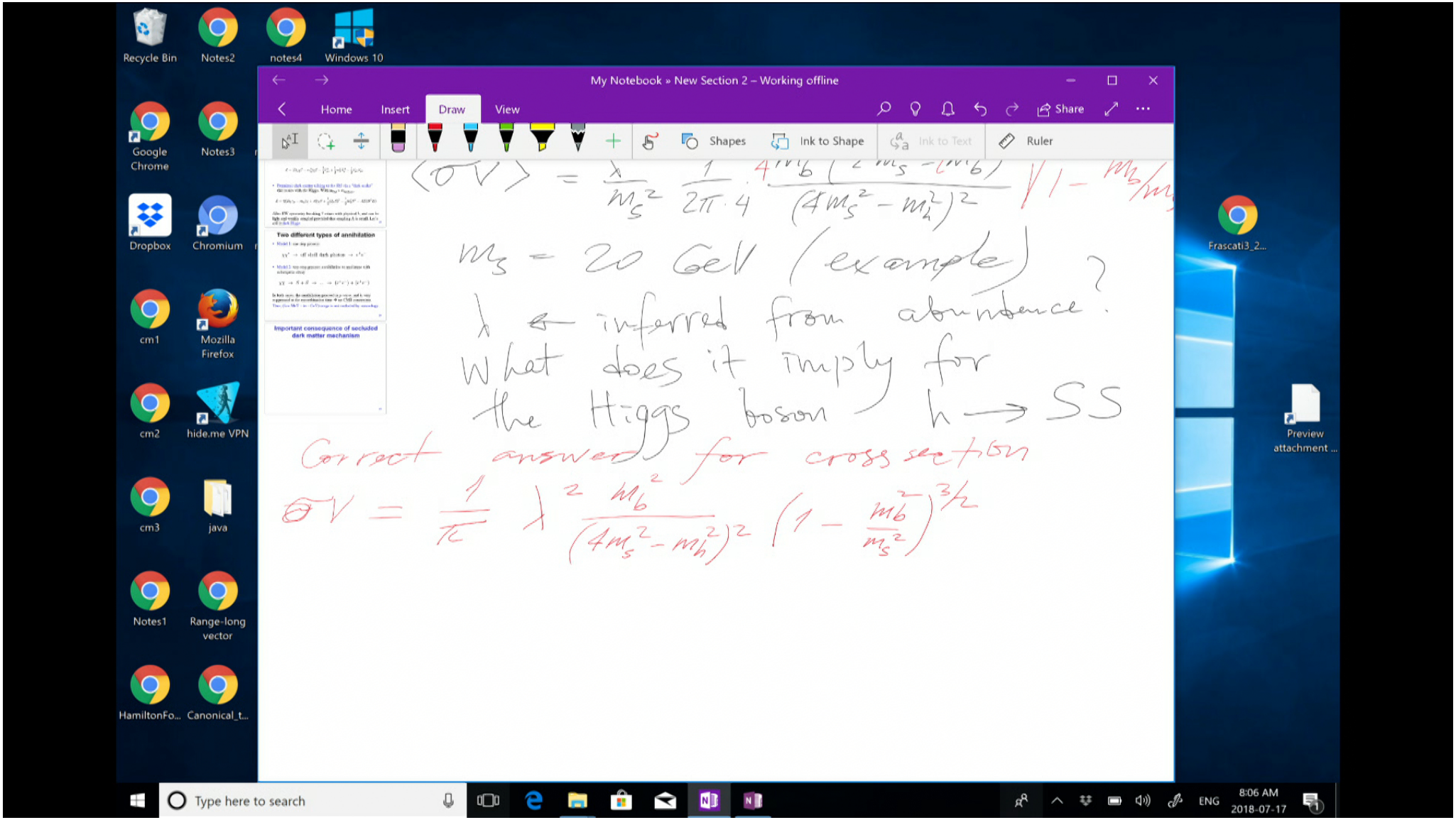

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super-WIMP
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Example: Higgs portal WIMP dark matter
SM + 1 singlet scalar S
S → -S
Unitary gauge
v = 246 GeV
h = "125 GeV"
Annihilation rate
Assume λ > 10^-7, thermal equilibrium
Two specific cases
m_S ≳ TeV
m_S < m_h/2
Large m_S
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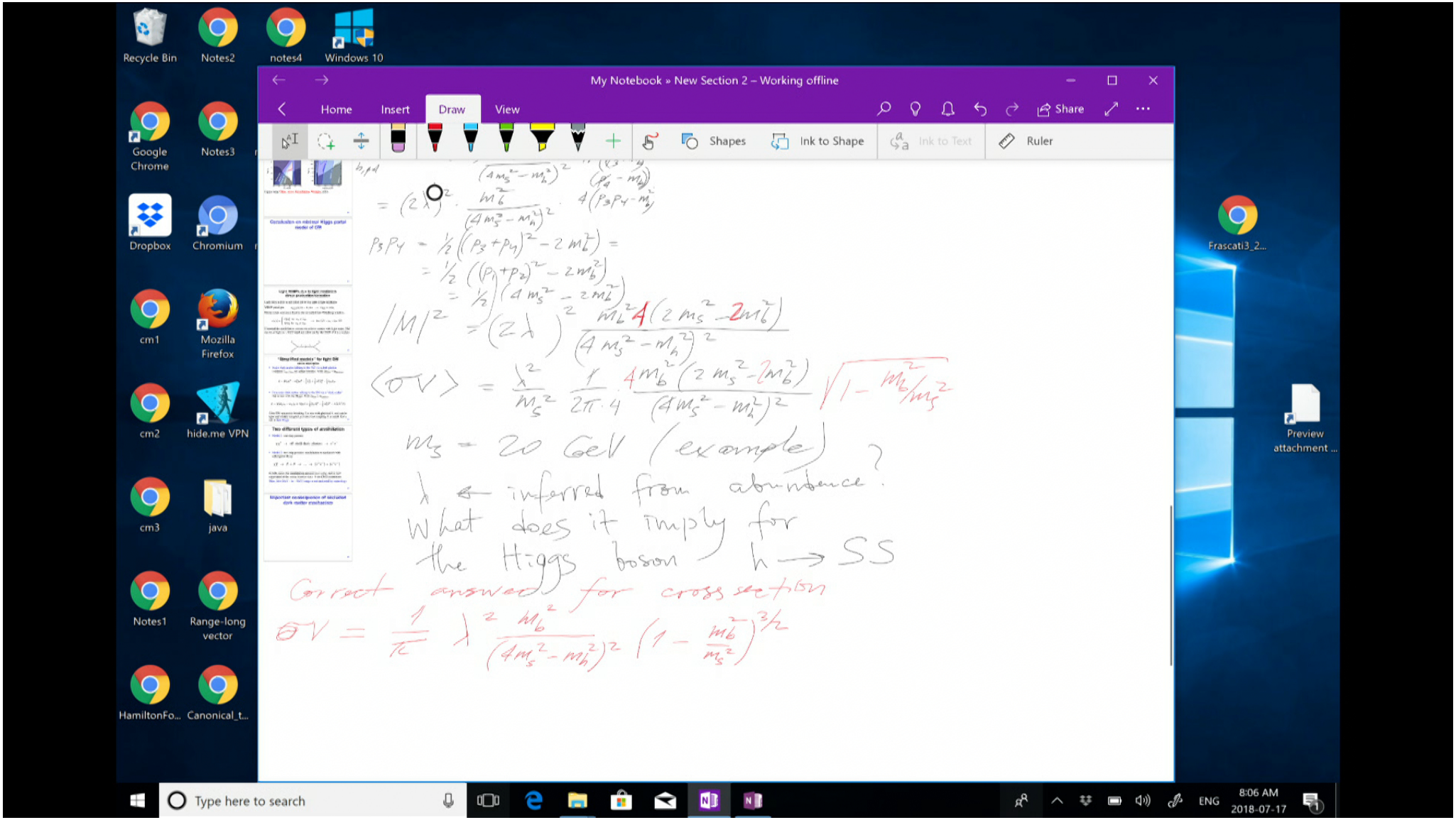

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Correction: identical particles in the final state
$0 < \theta < \pi/2$
$\Rightarrow \times 1/2$
$\sigma v = \frac{1}{4\pi} \frac{\lambda^2}{m_s^2}$
Compare to / pbn.
$\lambda \sim \sqrt{2\pi\, m^2 \cdot 1\,\text{pbn}}$
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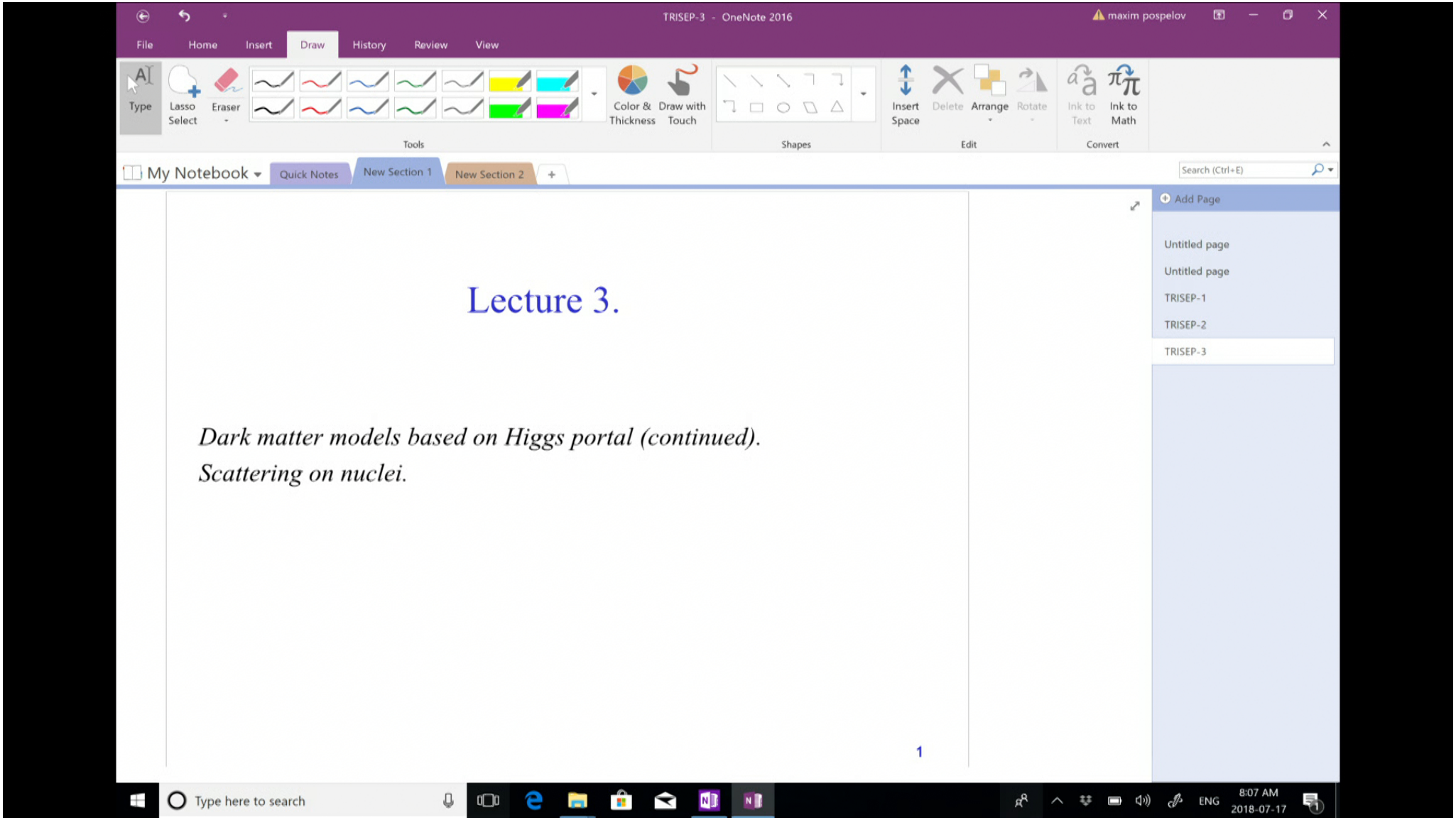

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Comparison with data
Simplified models of Higgs mediation
Updates on the minimal Higgs-mediated model
Conclusion on minimal Higgs portal model of DM
Light WIMPs due to light mediators direct production/detection
"Simplified models" for light DM sans complex
Two different types of annihilation
Important consequence of secluded dark matter mechanism
Conclusion: lighter than few 10 TeV
$2m_b < m_s < m_h/2$
10 GeV
$M = 2\lambda v \frac{1}{(2m_s)^2 - m_h^2} \frac{m_b}{v} \bar{b}b$
$\sum_{b,pol} |M|^2 = (2\lambda)^2 \frac{m_b^2}{(4m_s^2 - m_h^2)^2} \cdot Tr((\not{p}_3 + m_b)(\not{p}_4 - m_b)) \cdot 4(p_3 p_4 - m_b^2)$
$= (2\lambda)^2 \frac{m_b^2}{(4m_s^2 - m_h^2)^2} \cdot 4(p_3 p_4 - m_b^2)$
$p_3 p_4 = \frac{1}{2}((p_3 + p_4)^2 - 2m_b^2) = \frac{1}{2}((p_1 + p_2)^2 - 2m_b^2) = \frac{1}{2}(4m_s^2 - 2m_b^2)$
$|M|^2 = (2\lambda)^2 \frac{m_b^2 4(2m_s^2 - 2m_b^2)}{(4m_s^2 - m_h^2)^2}$
$\langle \sigma v \rangle = \frac{\lambda^2}{m_s^2} \frac{1}{2\pi \cdot 4} \frac{4m_b^2(2m_s^2 - 2m_b^2)}{(4m_s^2 - m_h^2)^2} \sqrt{1 - m_b^2/m_s^2}$
$m_s = 20$ GeV (example)
$\lambda \leftarrow$ inferred from abundance?
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Two different types of annihilation
Important consequence of secluded dark matter mechanism
$m_S = 20$ GeV (example)
λ ← inferred from abundance?
What does it imply for the Higgs boson $h \to SS$
Correct answer for cross section
$\sigma v = \frac{1}{\pi} \lambda^2 \frac{m_b^2}{(4m_S^2 - m_h^2)^2} \left(1 - \frac{m_b^2}{m_S^2}\right)^{3/2}$
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Lecture 3.
Dark matter models based on Higgs portal (continued).
Scattering on nuclei.
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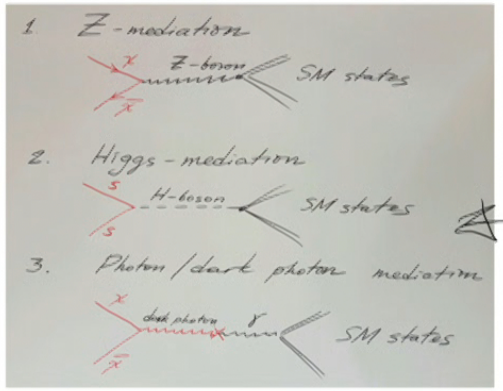
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Examples of DM-SM mediation



Very economical extensions of the SM.
DM particles themselves + may be extra mediator force. Can be very predictive.

If dark matter annihilation is mediated by weak scale particles, the mas of dark matter is confined to ~ 10 –to-10000 GeV (Lee, Weinberg)

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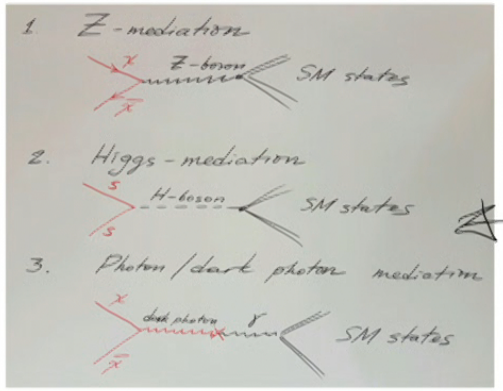
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1

Examples of DM-SM mediation



Very economical extensions of the SM. DM particles themselves + may be extra mediator force. Can be very predictive.

$m_s < m_h$

If dark matter annihilation is mediated by weak scale particles, the mas of dark matter is confined to ~ 10 –to-10000 GeV (Lee, Weinberg)

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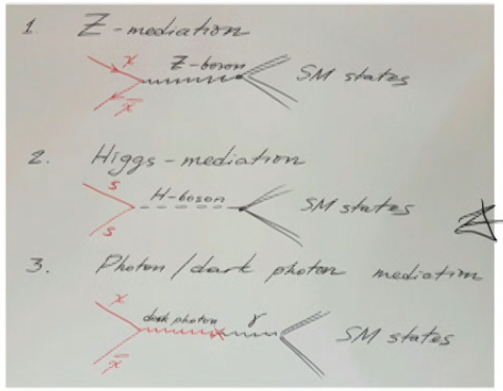
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1

Examples of DM-SM mediation



Very economical extensions of the SM.
DM particles themselves + may be extra mediator force. Can be very predictive.

$$m_s < \frac{m_h}{2}$$

$$\langle \sigma v \rangle_{ss \to \bar{b}b} \simeq 1\,\text{pbn}$$

If dark matter annihilation is mediated by weak scale particles, the mas of dark matter is confined to ~ 10 –to-10000 GeV (Lee, Weinberg)

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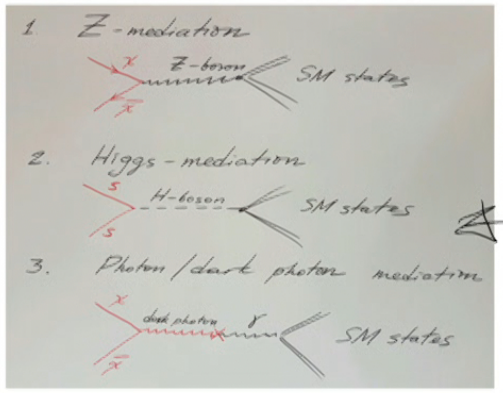
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Examples of DM-SM mediation



Very economical extensions of the SM. DM particles themselves + may be extra mediator force. Can be very predictive.

$$m_s < \frac{m_h}{2}$$

$$\langle \sigma v \rangle_{ss \to b\bar{b}} \simeq 1\,\text{pbn}$$

$$\downarrow \lambda^2$$

$$\hookrightarrow \Gamma_{h \to ss}$$

If dark matter annihilation is mediated by weak scale particles, the mas[2] of dark matter is confined to ~ 10 –to-10000 GeV (Lee, Weinberg)

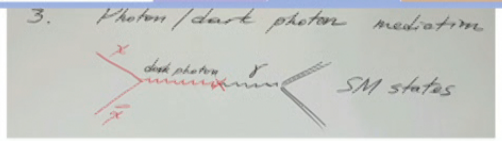
Annihilation rate

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Very economic
DM particle
extra mediate
predictive.

If dark matter annihilation is mediated by weak scale particles, the mas
of dark matter is confined to ~ 10 –to-10000 GeV (Lee, Weinberg)

$\langle \sigma v \rangle_{ss \to \bar{b}b} \simeq 1\,\text{pbn}$

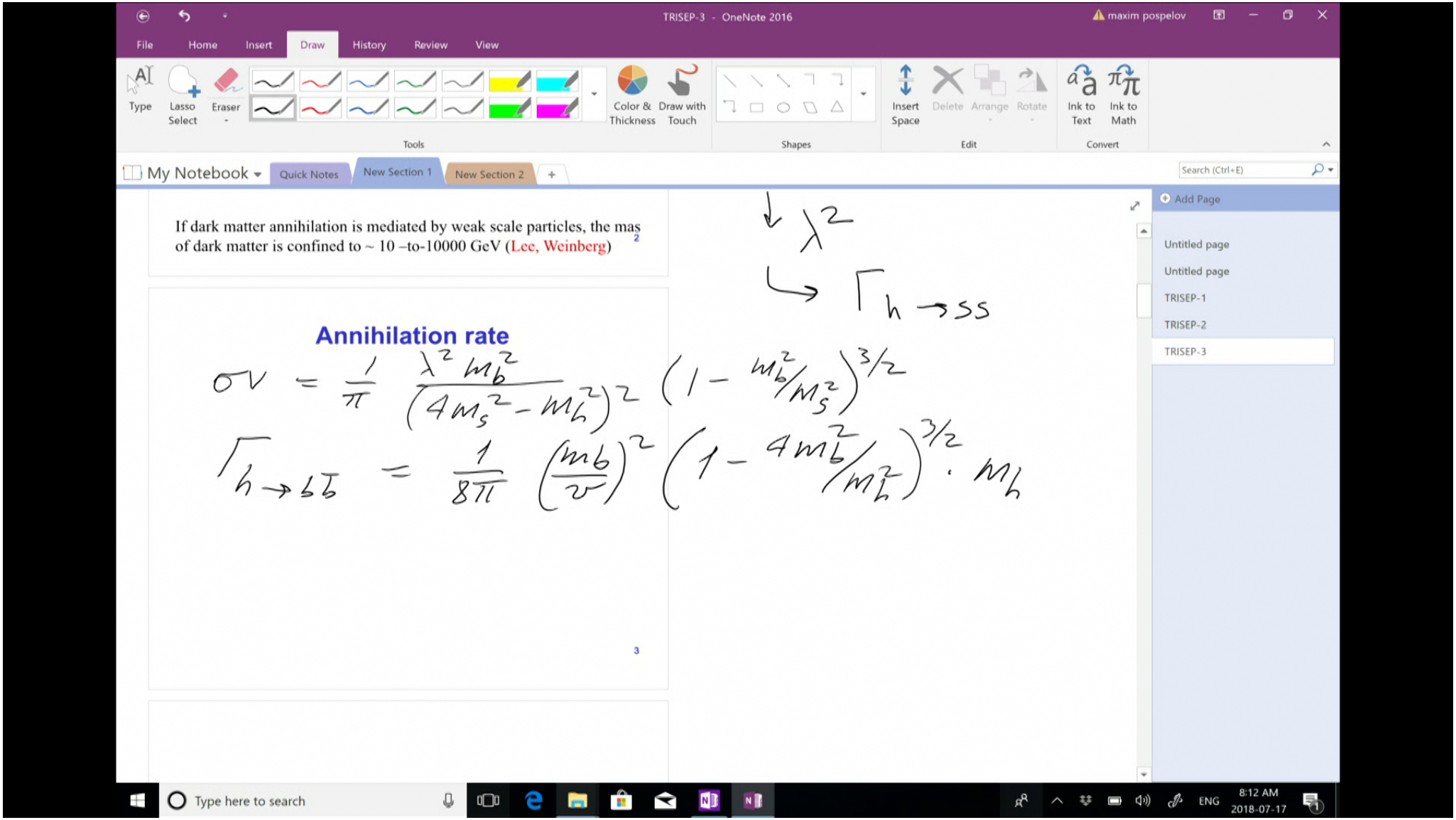
$\downarrow \lambda^2$

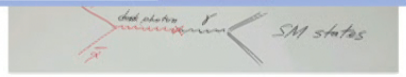
$\hookrightarrow \Gamma_{h \to ss}$

Annihilation rate

$$\sigma v = \frac{1}{\pi} \frac{\lambda^2 m_b^2}{(4m_s^2 - m_h^2)^2} \left(1 - m_b^2/m_s^2\right)^{3/2}$$

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If dark matter annihilation is mediated by weak scale particles, the mas of dark matter is confined to ~ 10 –to-10000 GeV (Lee, Weinberg)
2
Annihilation rate
$\sigma v = \frac{1}{\pi} \frac{\lambda^2 m_b^2}{(4m_s^2 - m_h^2)^2} (1 - m_b^2/m_s^2)^{3/2}$
$\Gamma_{h \to b\bar{b}} = \frac{1}{8\pi} \left(\frac{m_b}{v}\right)^2 (1 - 4m_b^2/m_h^2)^{3/2} \cdot m_h$
λ^2
$\hookrightarrow \Gamma_{h \to ss}$
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If dark matter annihilation is mediated by weak scale particles, the mas of dark matter is confined to ~ 10 –to-10000 GeV (Lee, Weinberg)

$ss \to b\bar{b}$ / = 1pbn

$\downarrow \lambda^2$

$\hookrightarrow \Gamma_{h \to ss}$

Annihilation rate

$$\sigma v = \frac{1}{\pi} \frac{\lambda^2 m_b^2}{(4m_s^2 - m_h^2)^2} \left(1 - m_b^2/m_s^2\right)^{3/2}$$

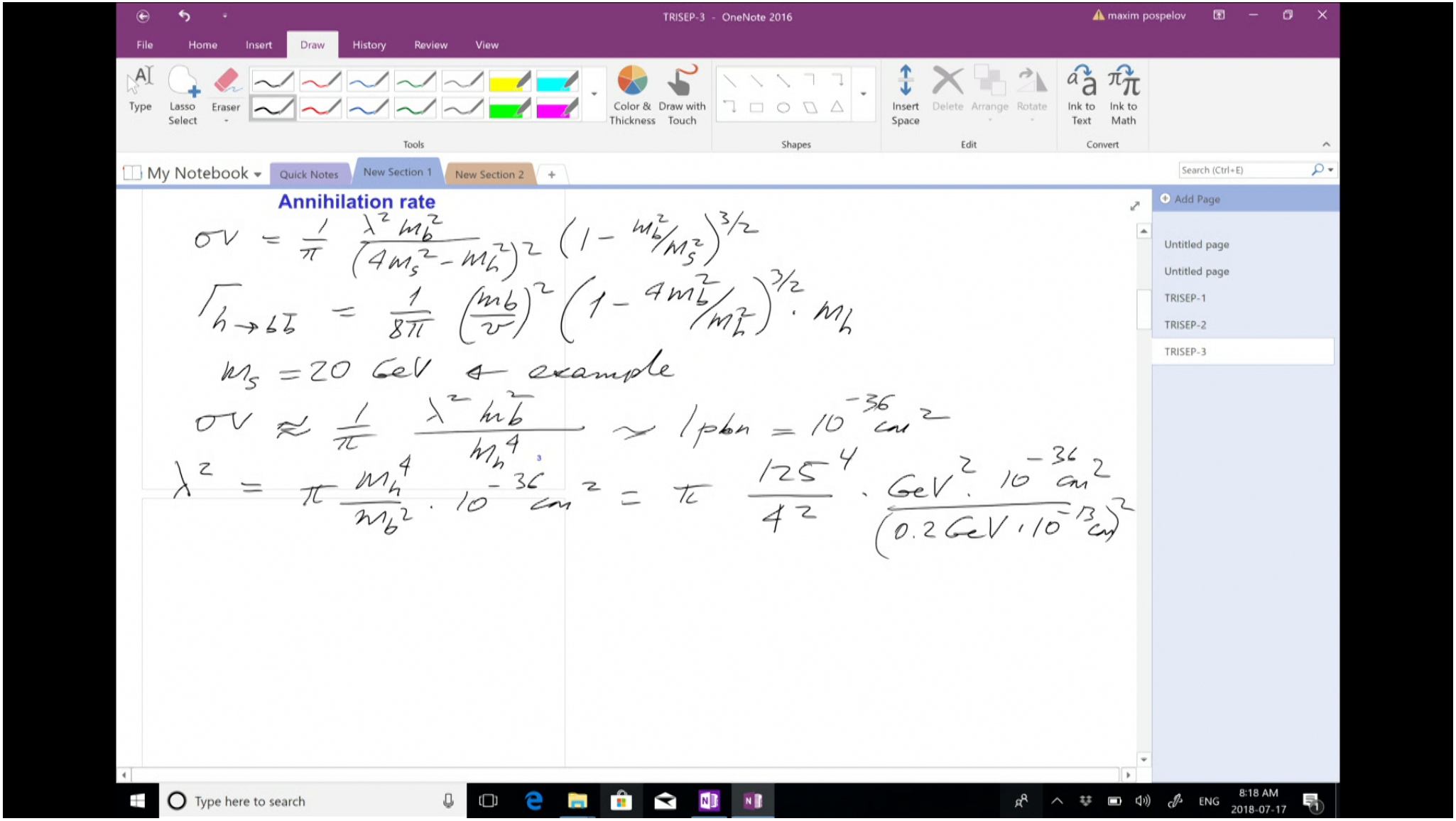
$$\Gamma_{h \to b\bar{b}} = \frac{1}{8\pi} \left(\frac{m_b}{v}\right)^2 \left(1 - 4m_b^2/m_h^2\right)^{3/2} \cdot m_h$$

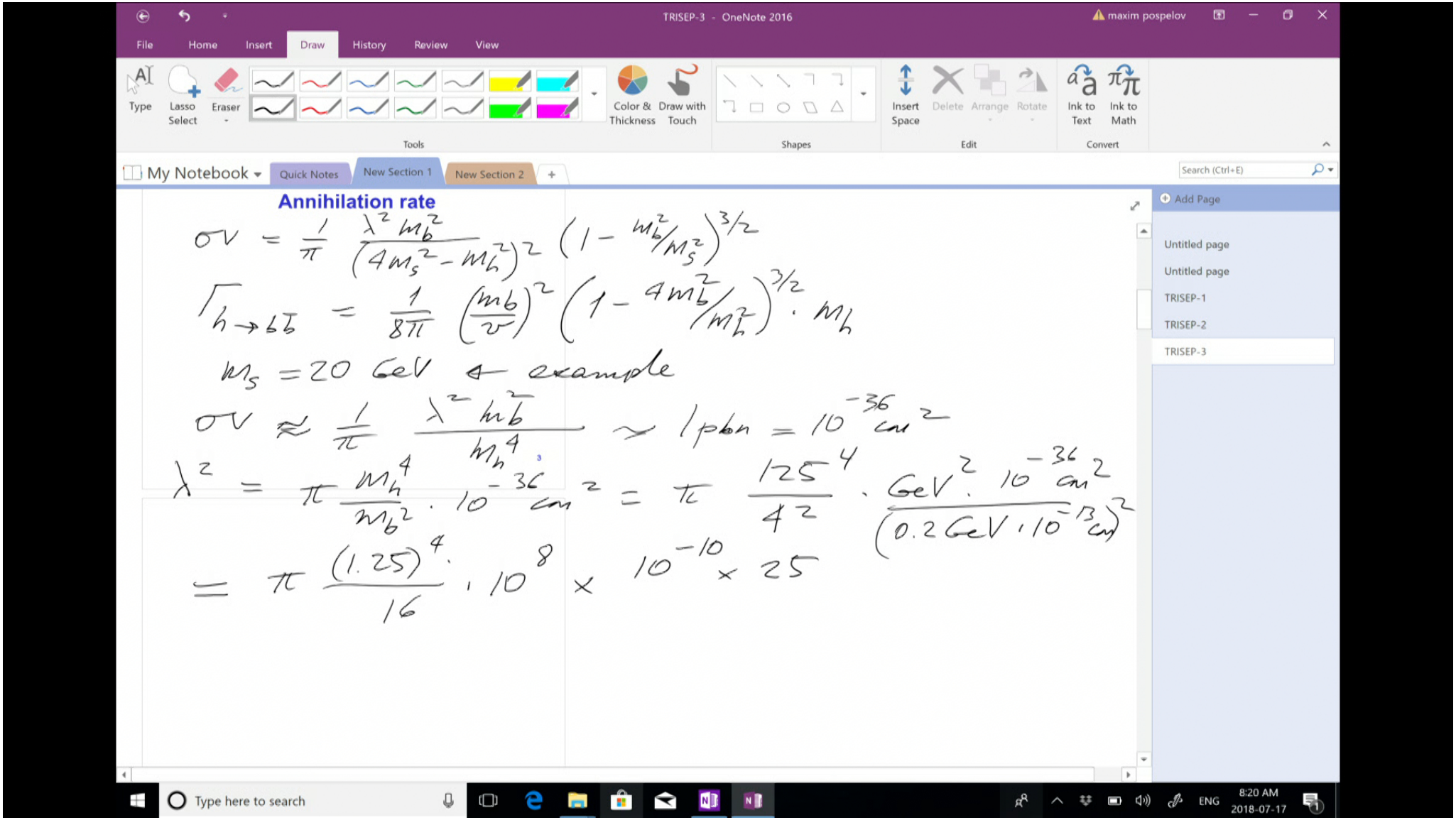
$m_s = 20$ GeV ← example

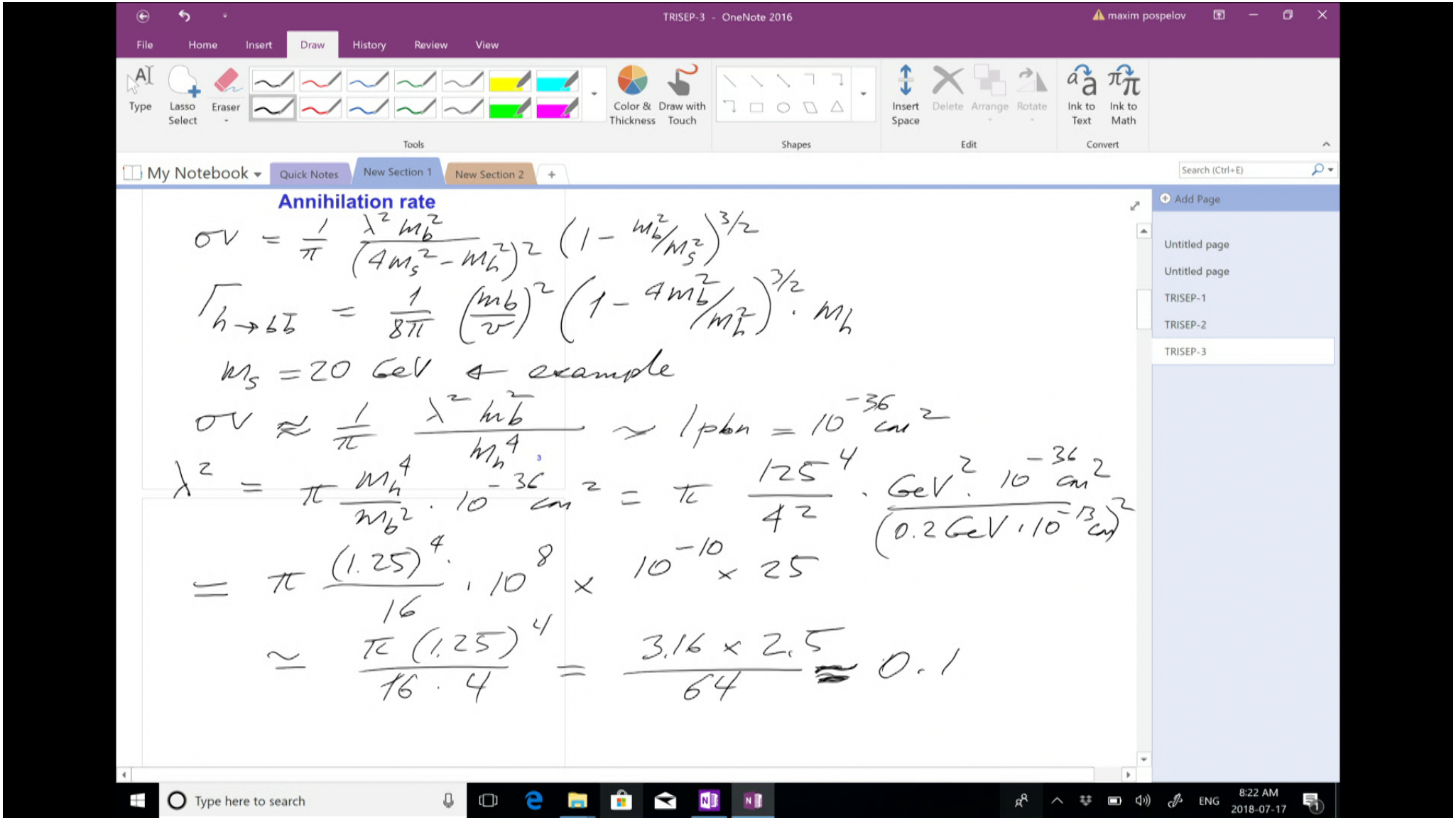
$$\sigma v \approx \frac{1}{\pi} \frac{\lambda^2 m_b^2}{m_h^4}$$

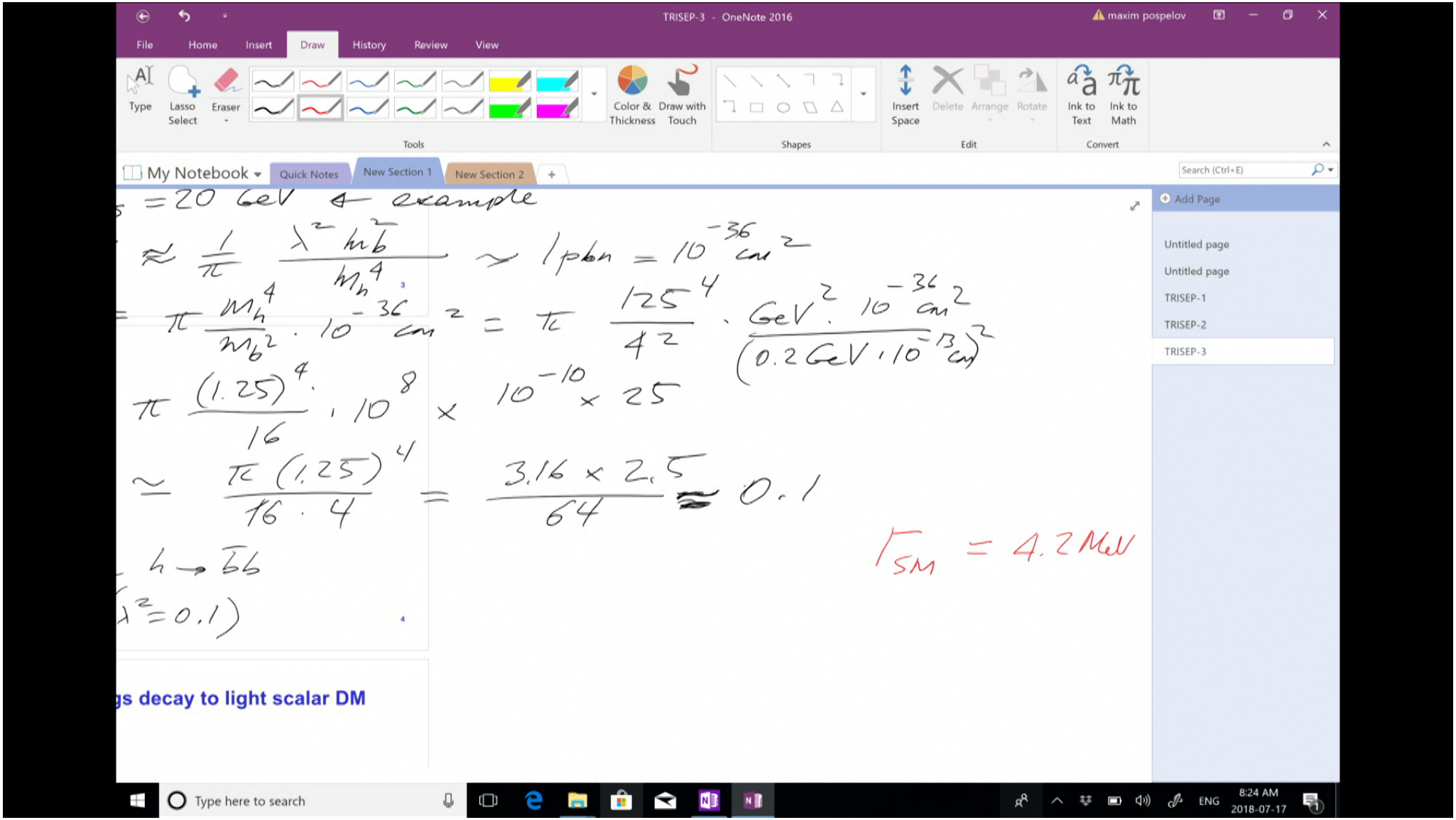
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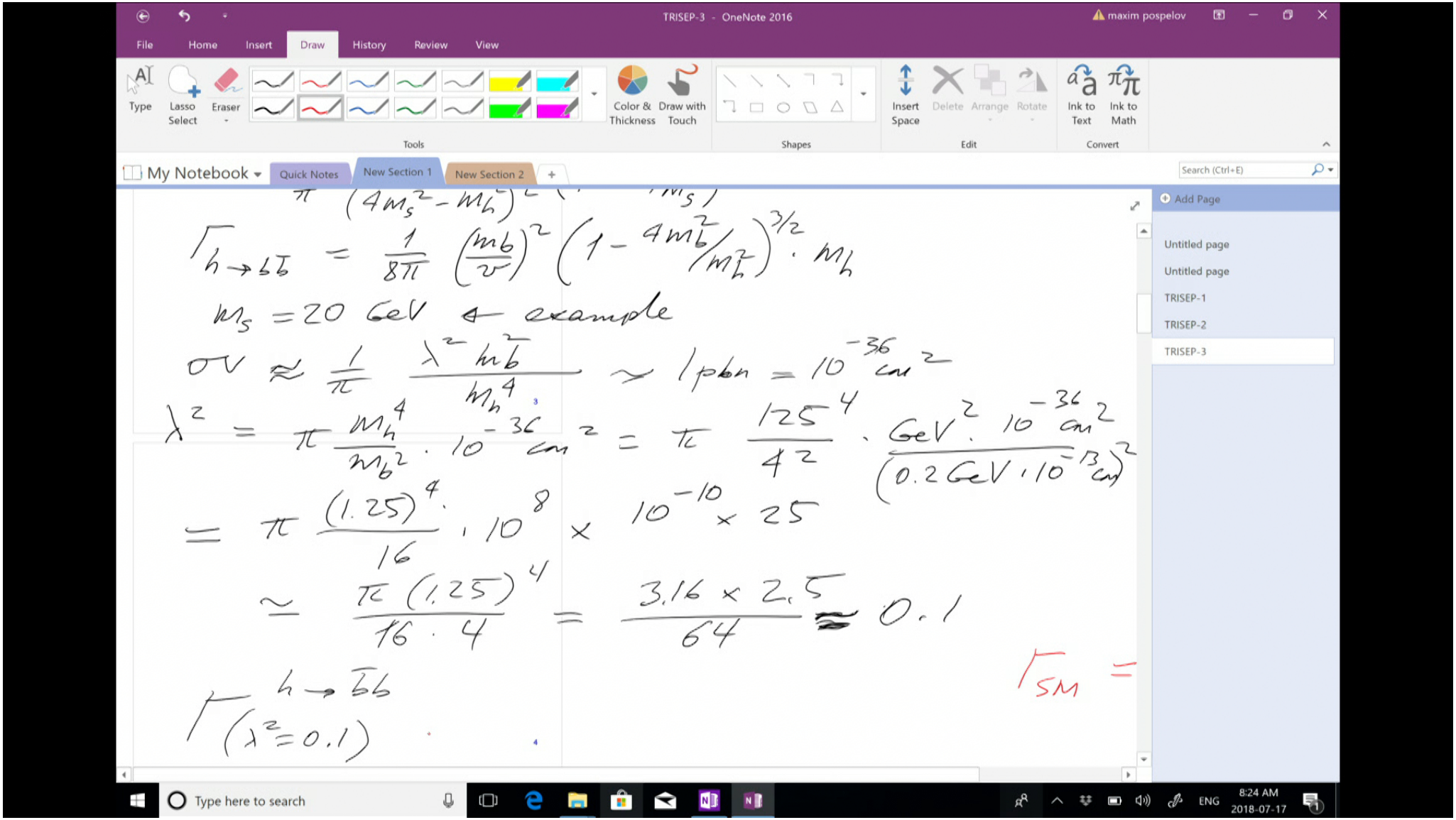
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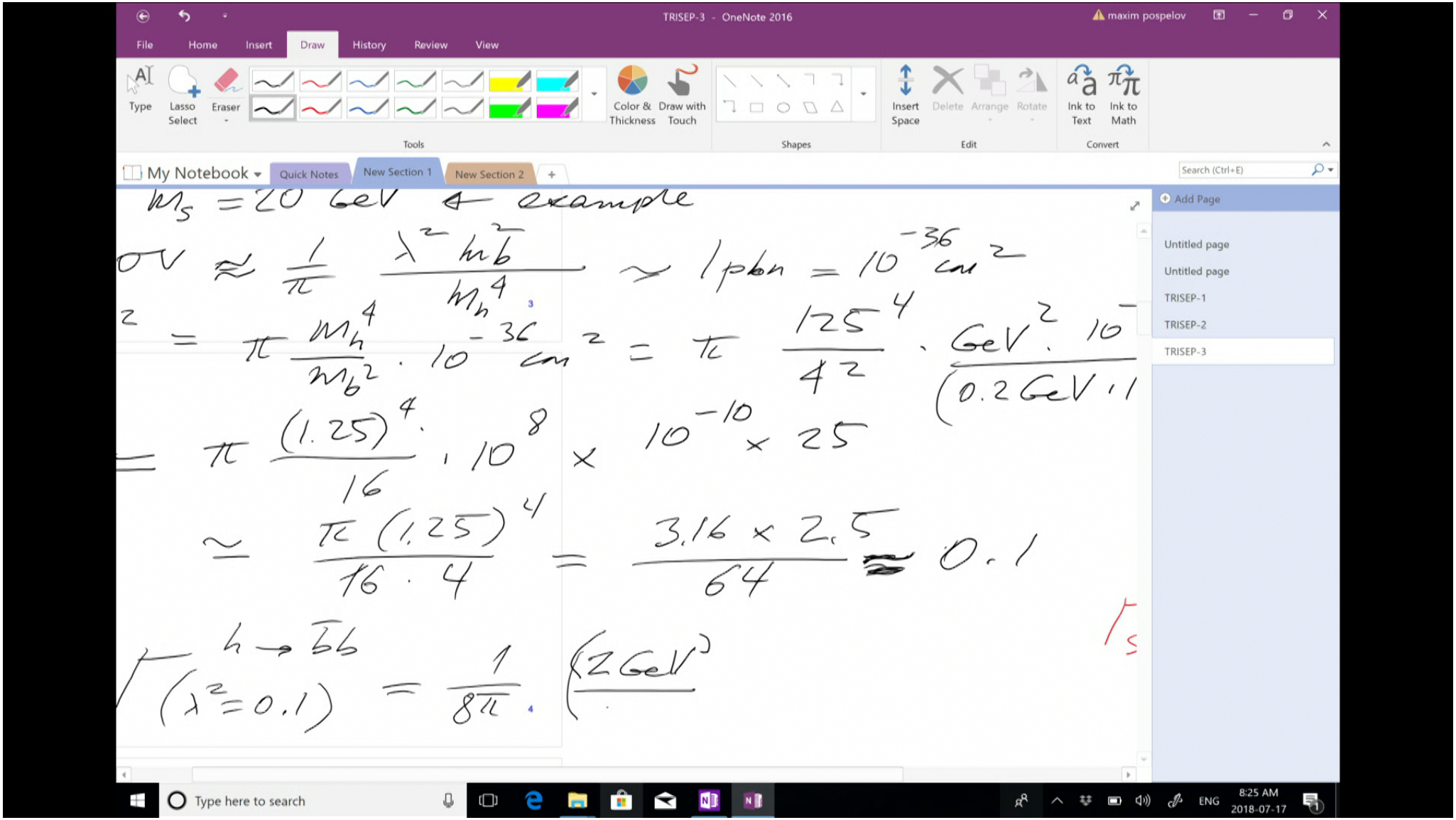

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Annihilation rate
$\sigma v = \frac{1}{\pi} \frac{\lambda^2 m_b^2}{(4m_s^2 - m_h^2)^2} \left(1 - m_b^2/m_s^2\right)^{3/2}$
$\Gamma_{h\to b\bar{b}} = \frac{1}{8\pi} \left(\frac{m_b}{v}\right)^2 \left(1 - 4m_b^2/m_h^2\right)^{3/2} \cdot m_h$
$m_s = 20$ GeV ← example
$\sigma v \approx \frac{1}{\pi} \frac{\lambda^2 m_b^2}{m_h^4} \sim 1\,\text{pbn} = 10^{-36}\,\text{cm}^2$
$\lambda^2 = \pi \frac{m_h^4}{m_b^2} \cdot 10^{-36}\,\text{cm}^2 = \pi \frac{125^4}{4^2} \cdot \frac{\text{GeV}^2 \cdot 10^{-36}\,\text{cm}^2}{(0.2\,\text{GeV} \cdot 10^{13}\,\text{cm})^2}$
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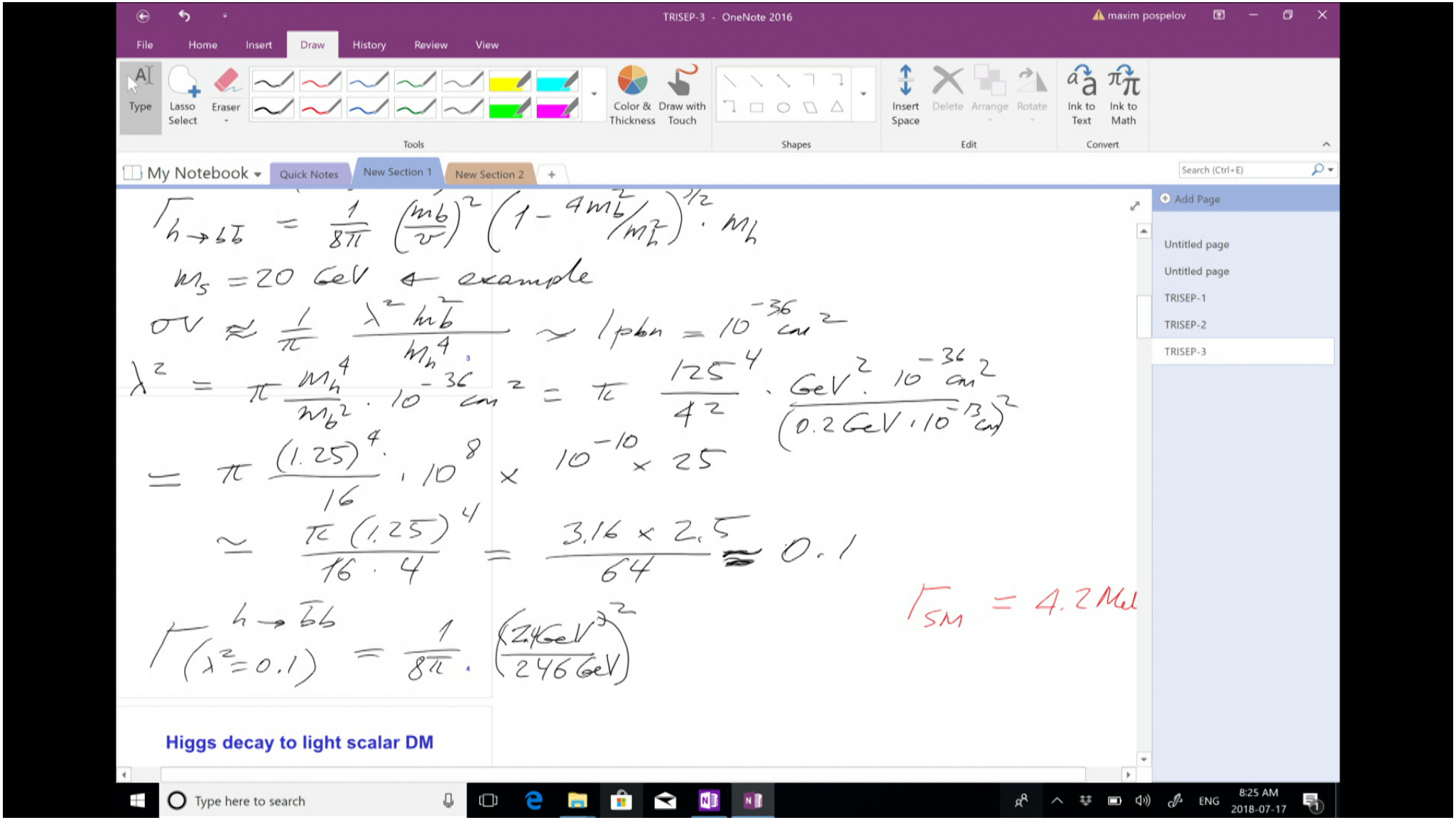

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$m_s = 20$ GeV ← example
$\sigma v \approx \frac{1}{\pi} \frac{\lambda^2 m_b^2}{m_h^4} \sim 1\,\text{pbn} = 10^{-36}\,\text{cm}^2$
$\lambda^2 = \pi \frac{m_h^4}{m_b^2} \cdot 10^{-36}\,\text{cm}^2 = \pi \frac{125^4}{4^2} \cdot \frac{\text{GeV}^2 \cdot 10^{-36}\,\text{cm}^2}{(0.2\,\text{GeV} \cdot 10^{-13}\,\text{cm})^2}$
$= \pi \frac{(1.25)^4}{16} \cdot 10^8 \times 10^{-10} \times 25$
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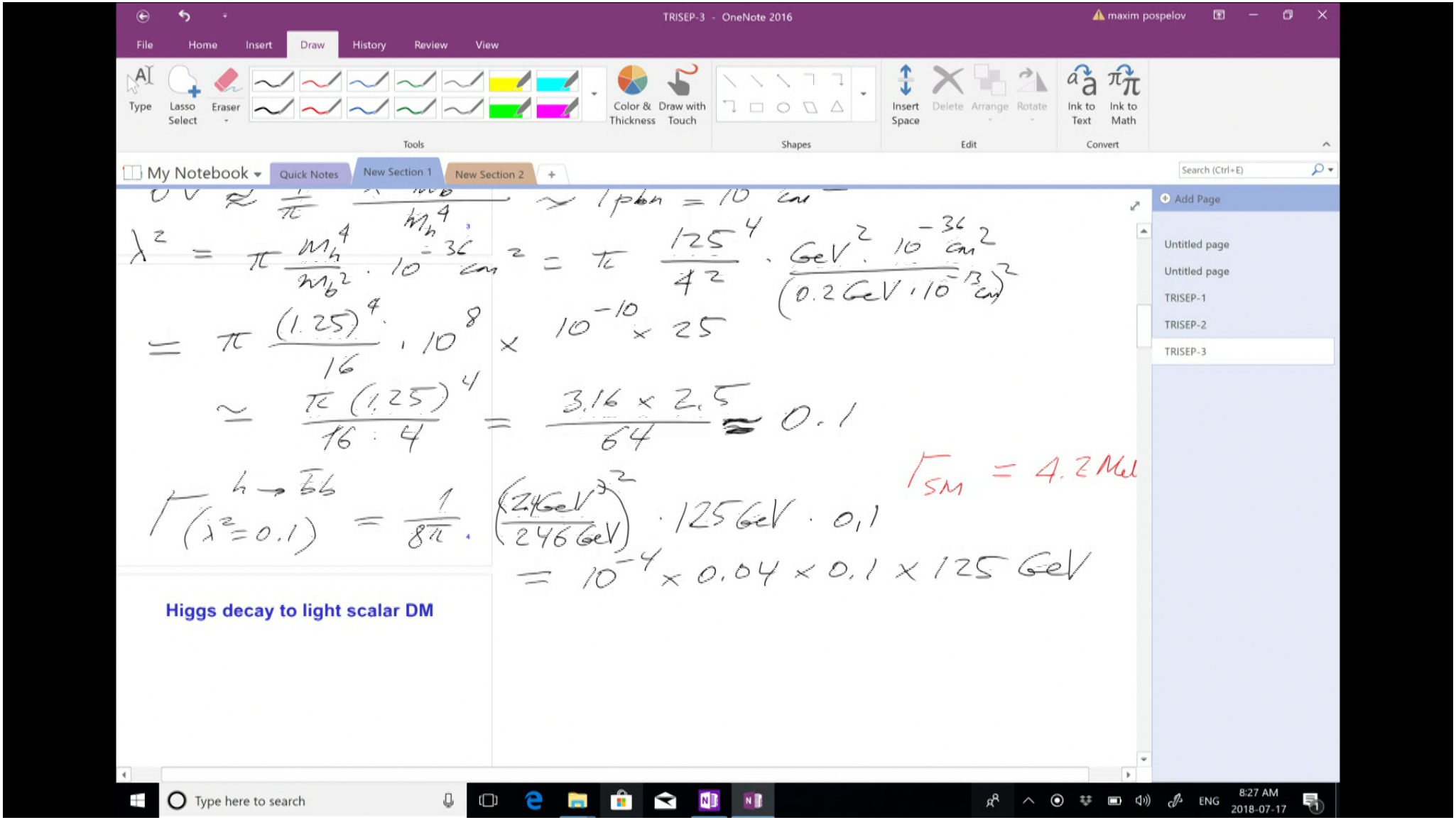

TRISEP-3 - OneNote 2016
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Annihilation rate
$\sigma v = \frac{1}{\pi} \frac{\lambda^2 m_b^2}{(4m_s^2 - m_h^2)^2} \left(1 - m_b^2/m_s^2\right)^{3/2}$
$\Gamma_{h\to b\bar{b}} = \frac{1}{8\pi} \left(\frac{m_b}{v}\right)^2 \left(1 - 4m_b^2/m_h^2\right)^{3/2} \cdot m_h$
$m_s = 20$ GeV ← example
$\sigma v \approx \frac{1}{\pi} \frac{\lambda^2 m_b^2}{m_h^4} \sim 1\,\text{pbn} = 10^{-36}\,\text{cm}^2$
$\lambda^2 = \pi \frac{m_h^4}{m_b^2} \cdot 10^{-36}\,\text{cm}^2 = \pi \frac{125^4}{4^2} \cdot \frac{\text{GeV}^2 \cdot 10^{-36}\,\text{cm}^2}{(0.2\,\text{GeV} \cdot 10^{13}\,\text{cm})^2}$
$= \pi \frac{(1.25)^4}{16} \cdot 10^8 \times 10^{-10} \times 25$
$\sim \frac{\pi (1.25)^4}{16 \cdot 4} = \frac{3.16 \times 2.5}{64} \approx 0.1$
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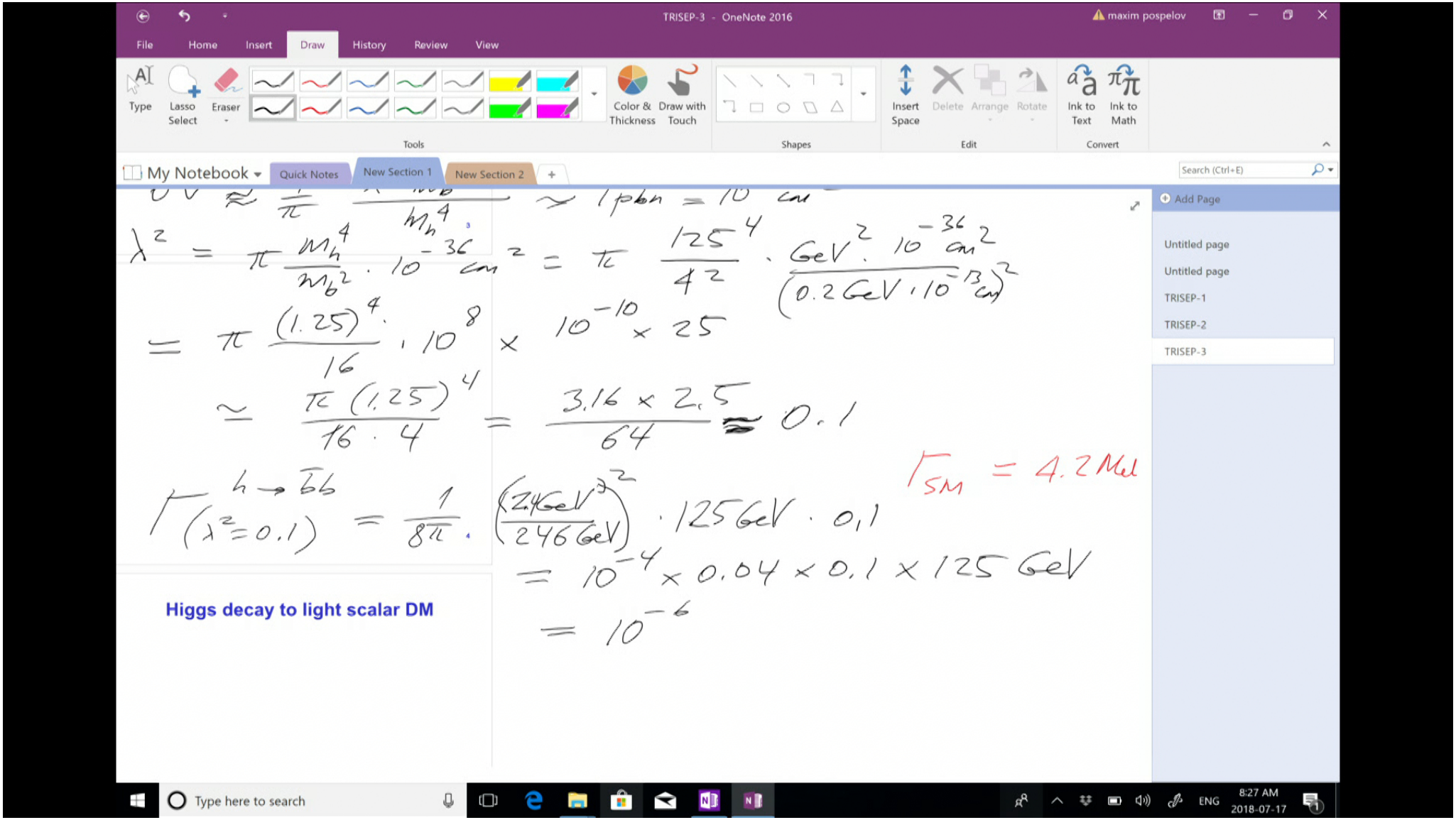

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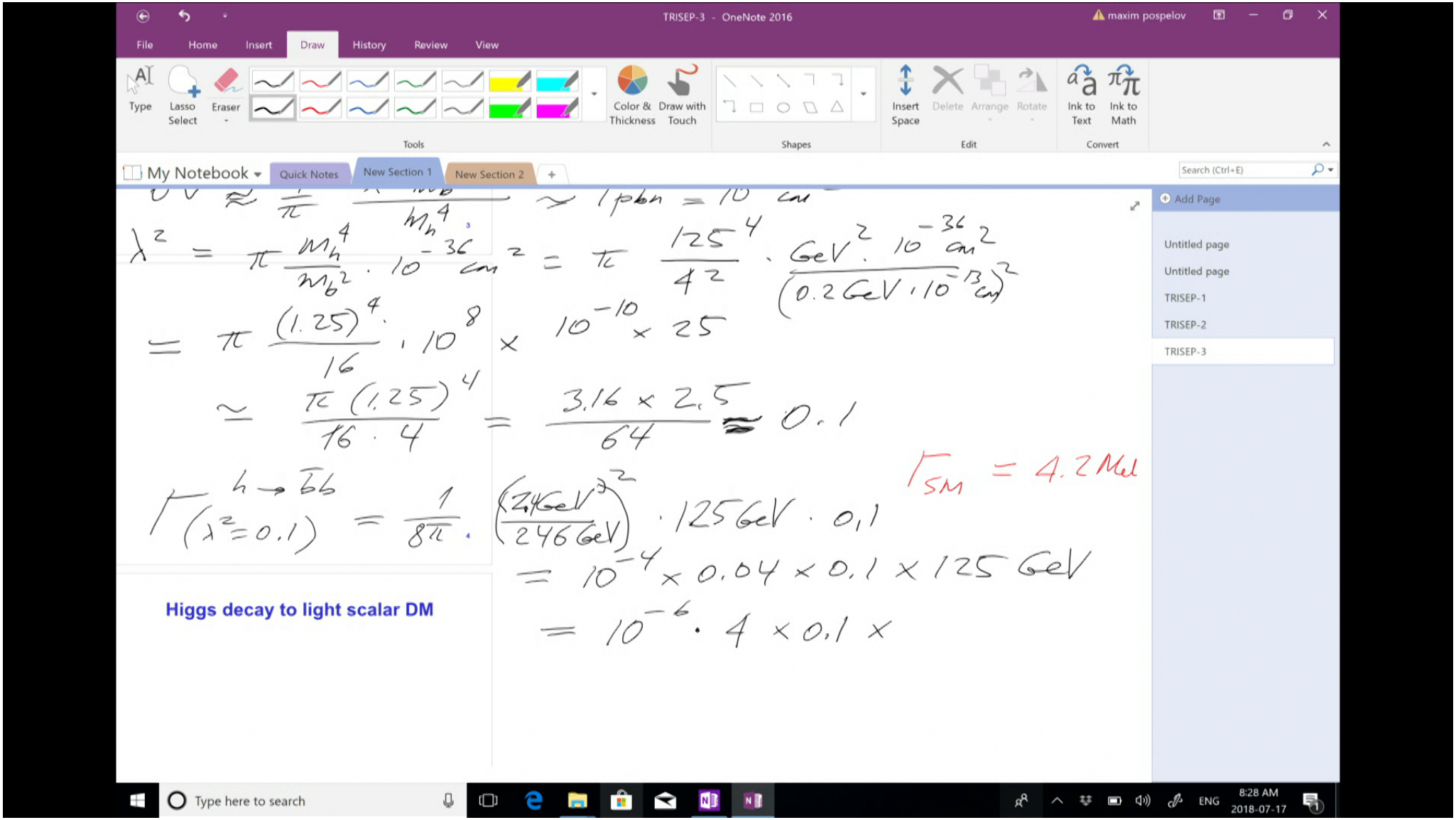

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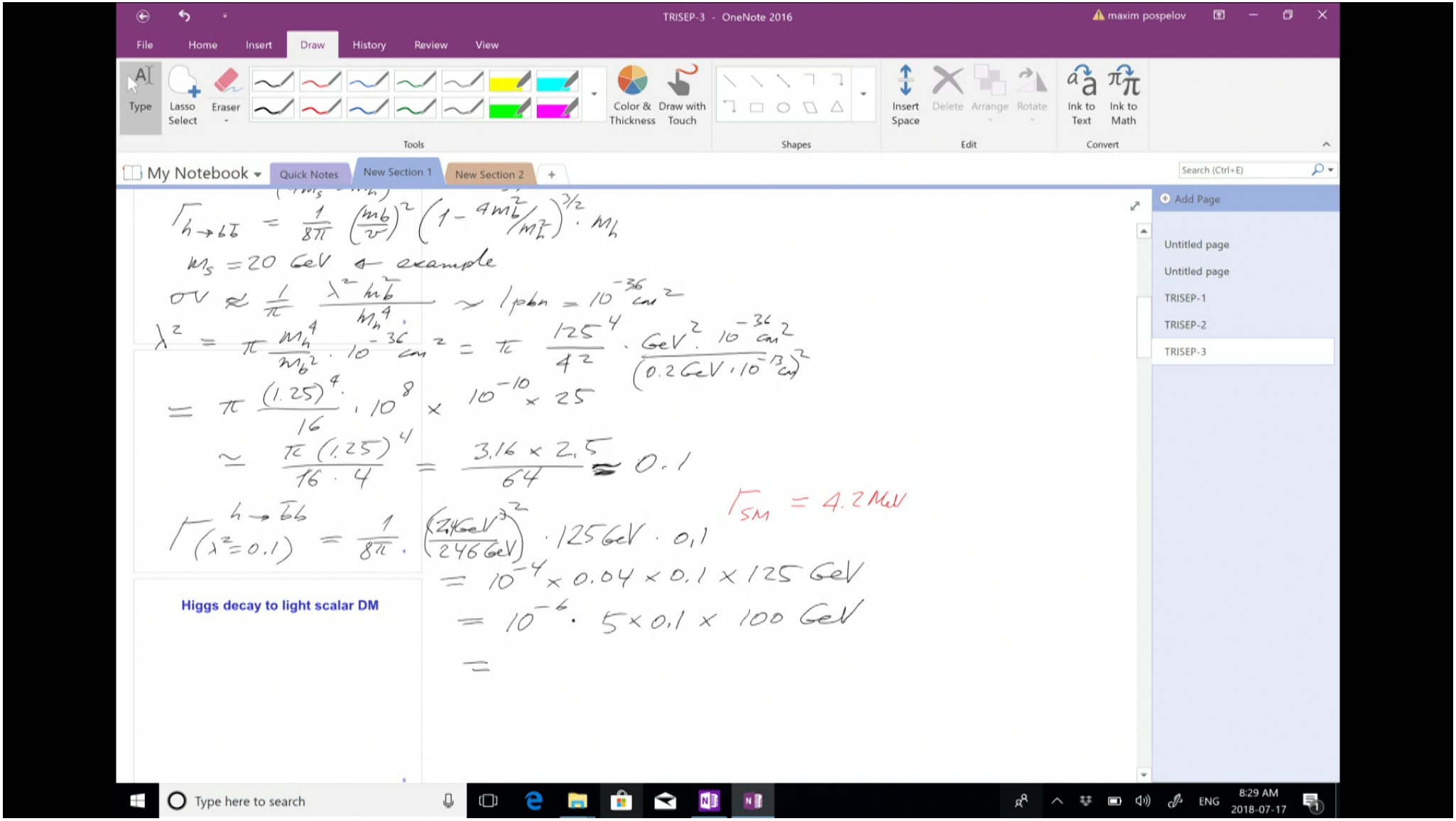

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$M_S = 20$ GeV ← example
$\sigma v \approx \frac{1}{\pi} \frac{\lambda^2 m_b^2}{m_h^4} \sim 1\,\text{pbn} = 10^{-36}\,\text{cm}^2$
$= \pi \frac{m_h^4}{m_b^2} \cdot 10^{-36}\,\text{cm}^2 = \pi \frac{125^4}{4^2} \cdot \frac{\text{GeV}^2 \cdot 10^{-}}{(0.2\,\text{GeV} \cdot 1}$
$= \pi \frac{(1.25)^4}{16} \cdot 10^8 \times 10^{-10} \times 25$
$\sim \frac{\pi (1.25)^4}{16 \cdot 4} = \frac{3.16 \times 2.5}{64} \sim 0.1$
$\Gamma_{h \to \bar{b}b} (\lambda^2 = 0.1) = \frac{1}{8\pi} \cdot (2\,\text{GeV})$
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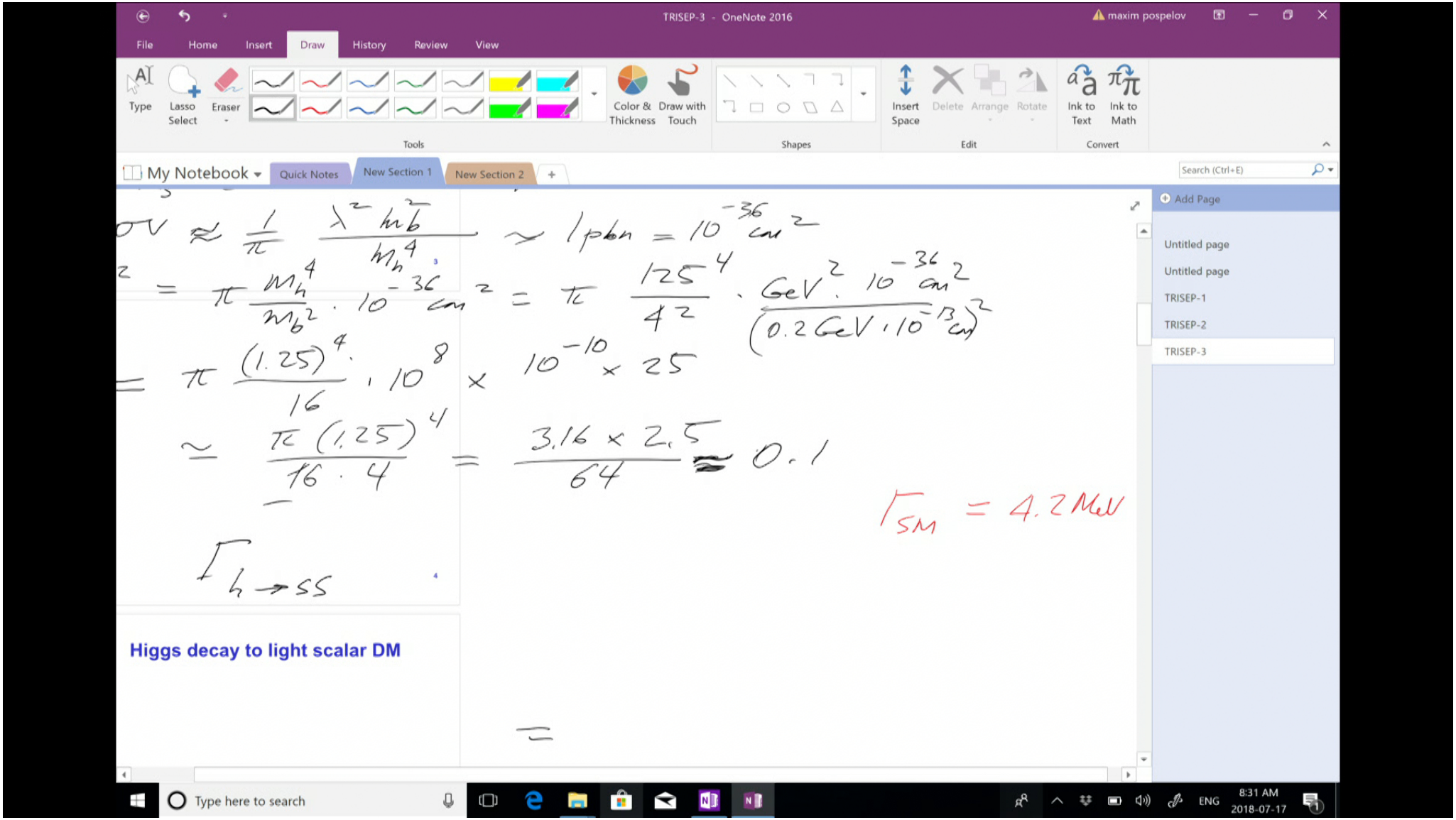

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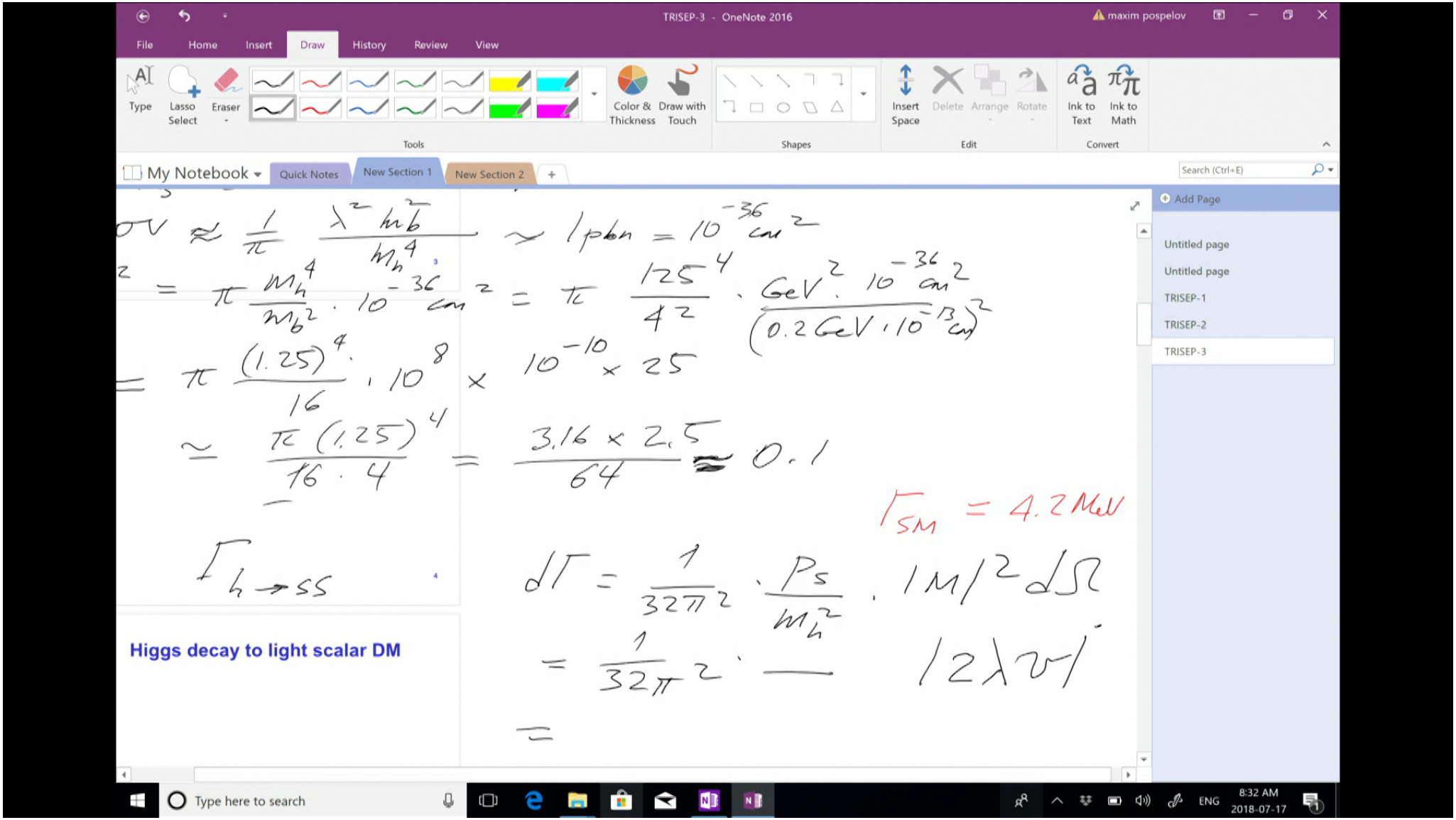

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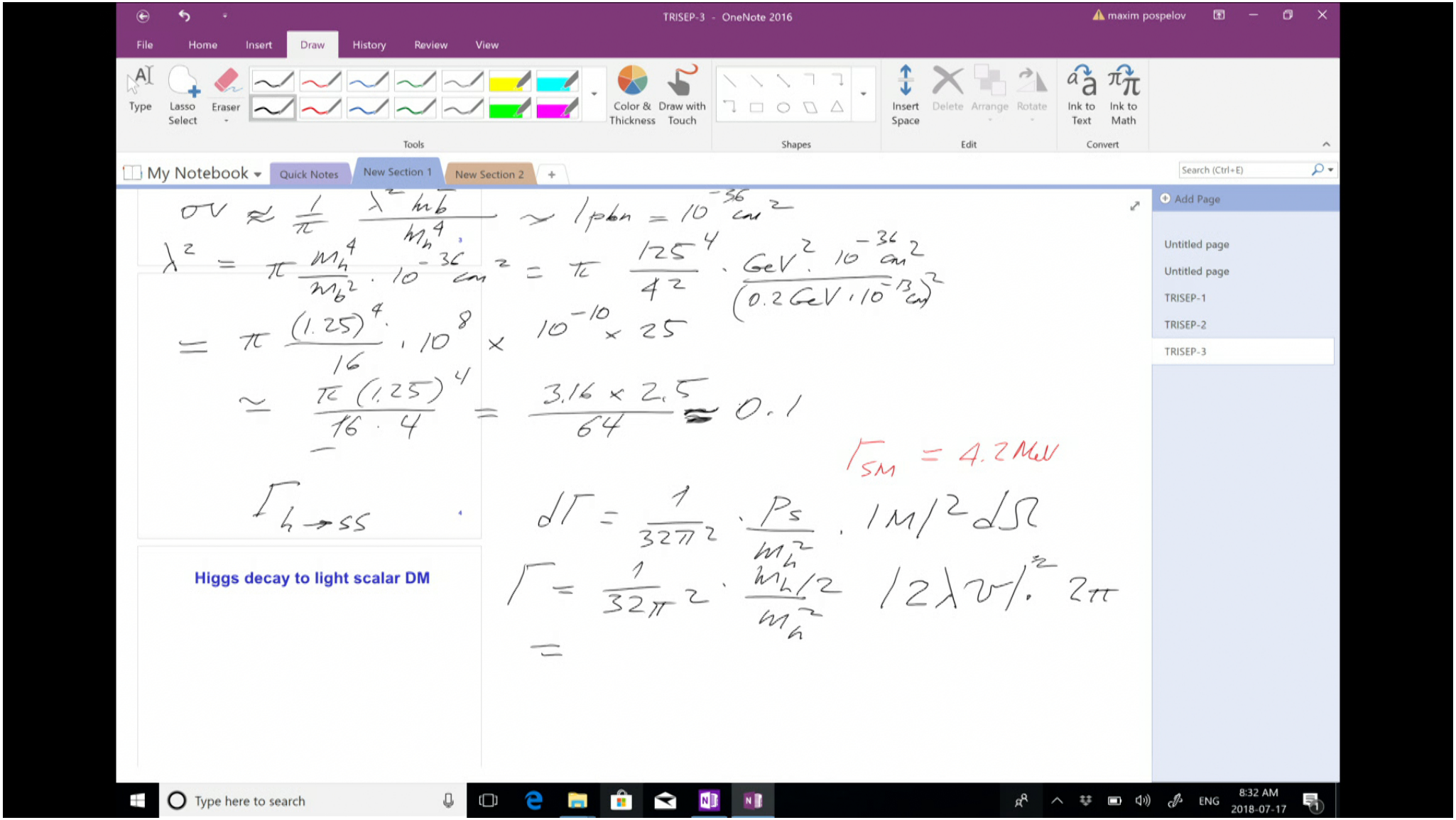

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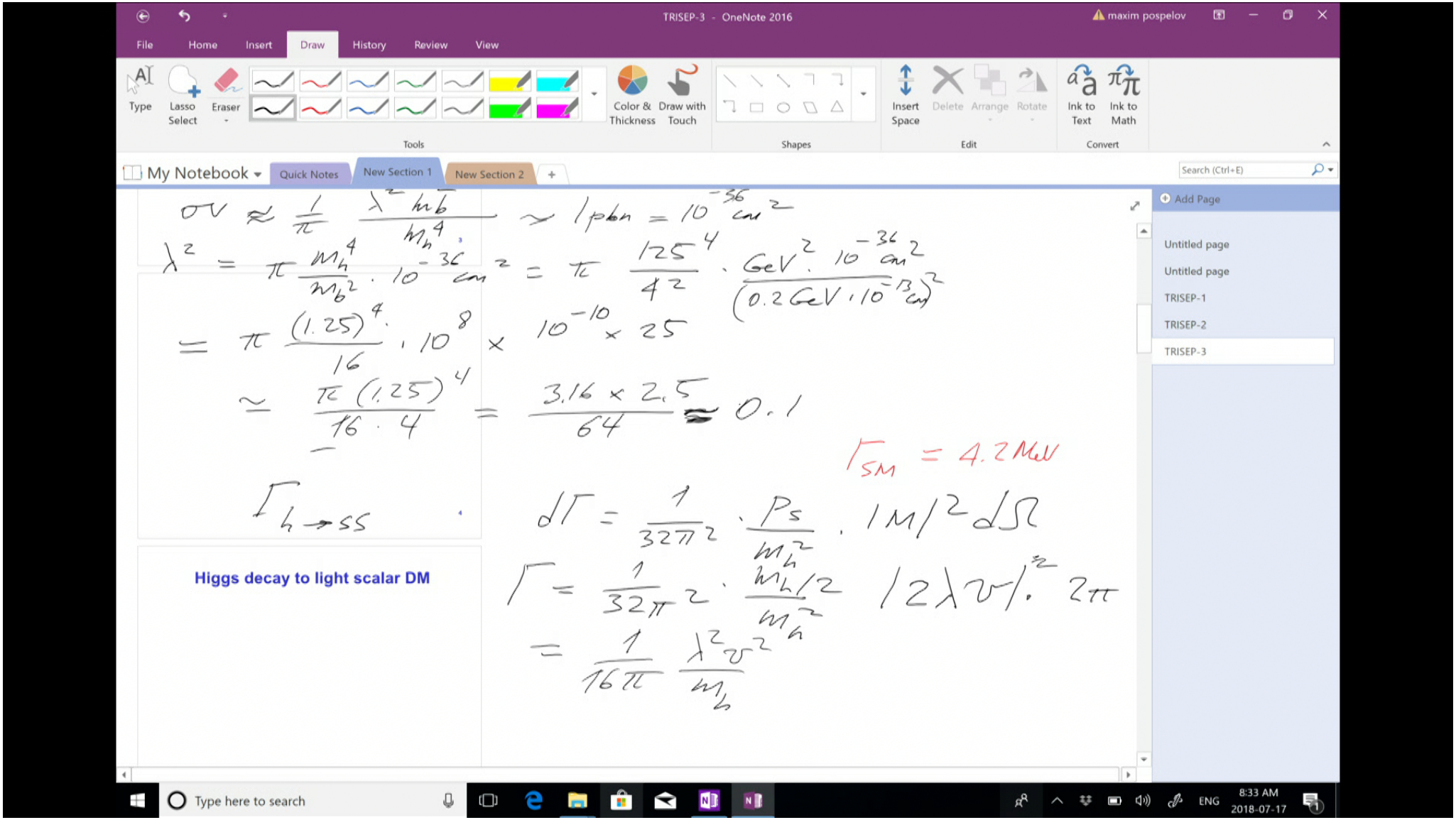

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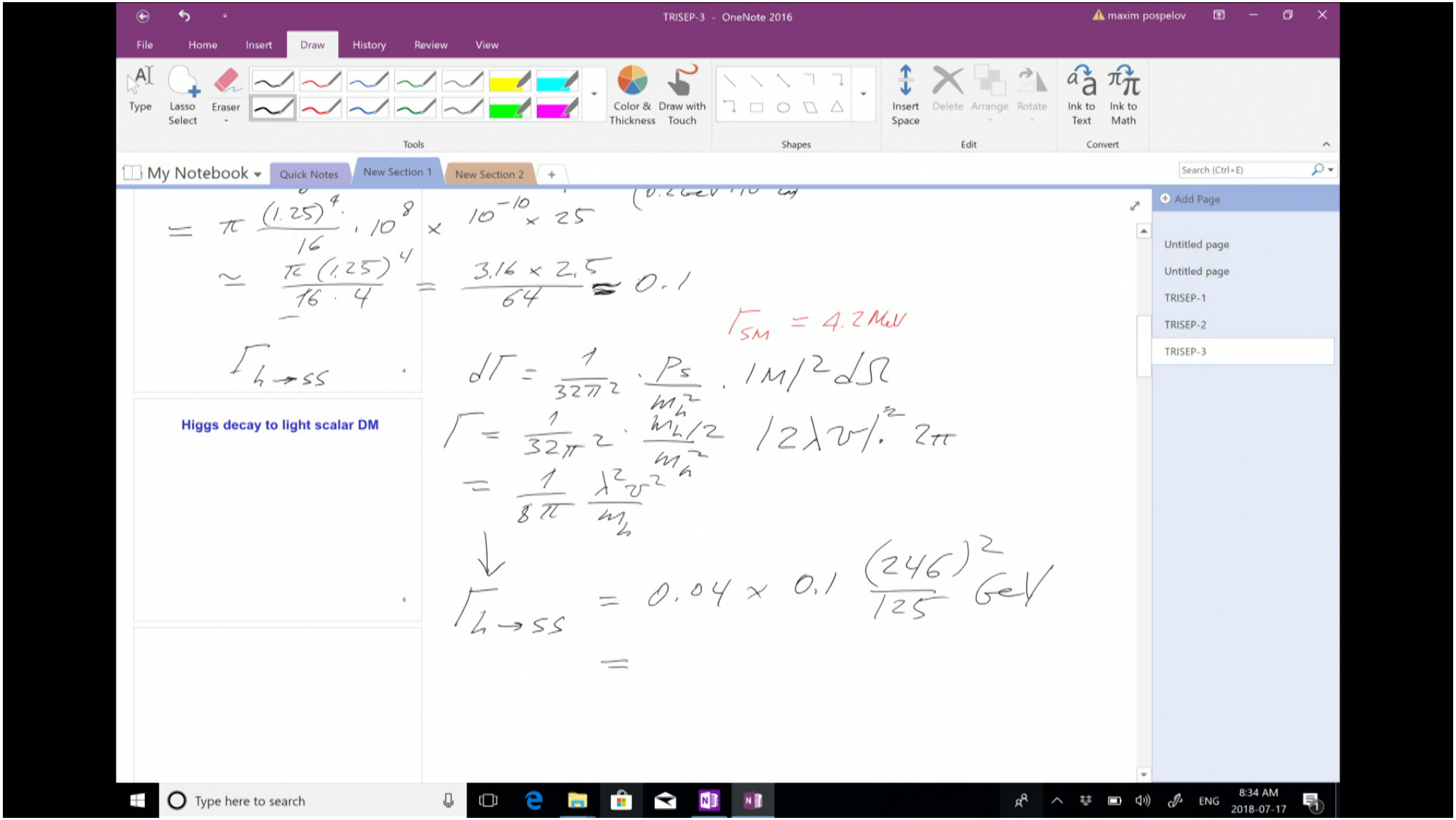

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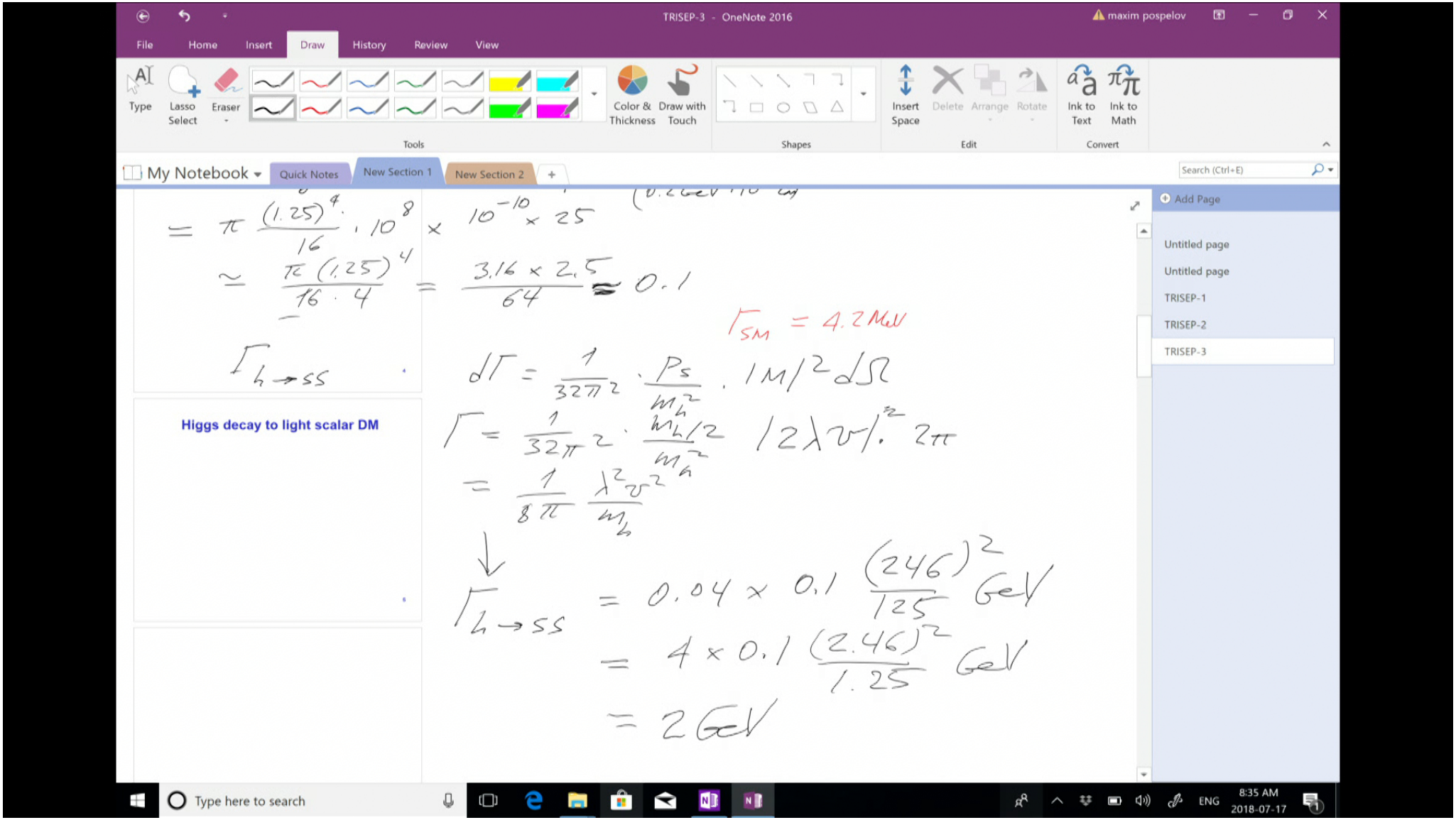

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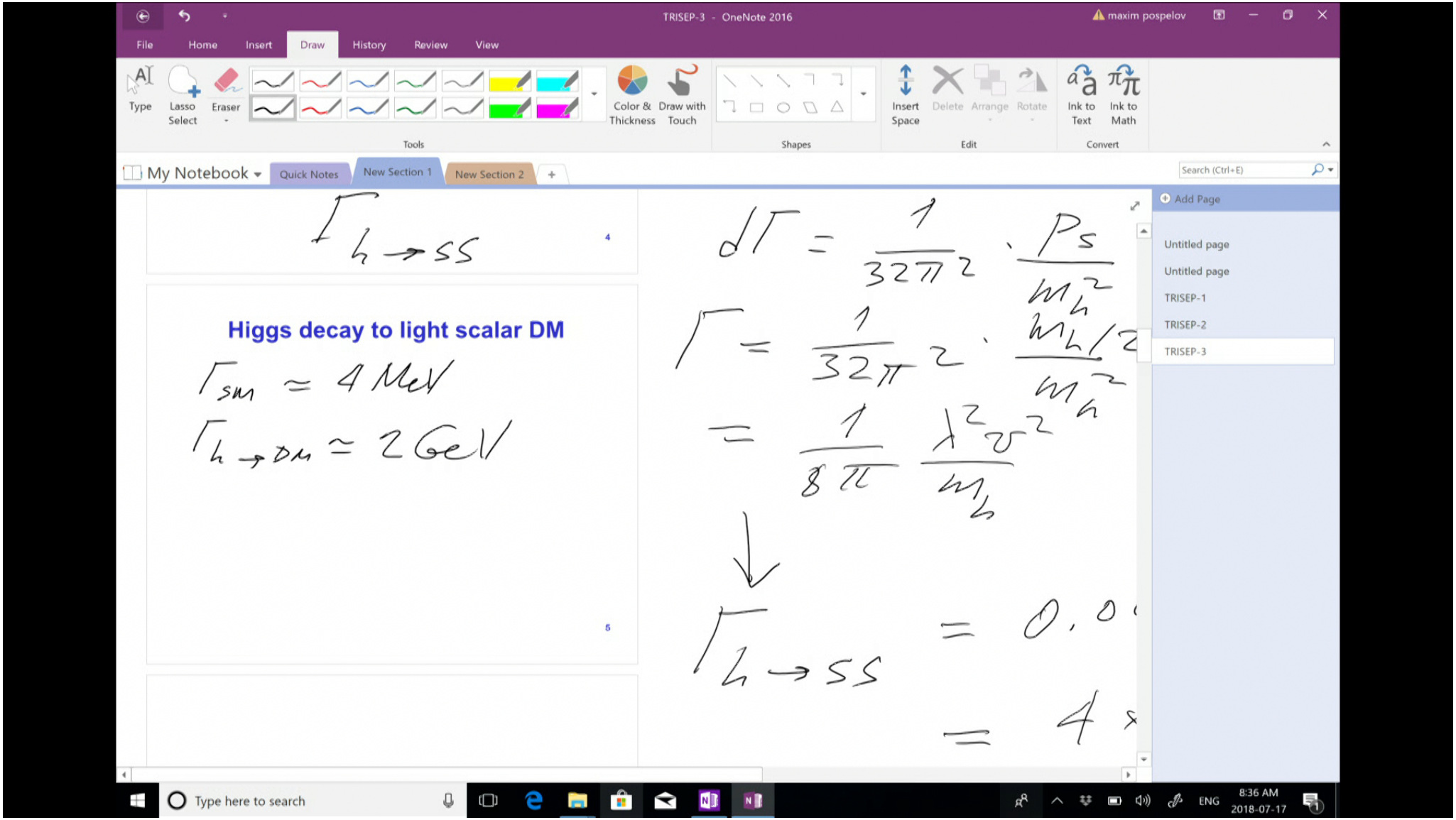

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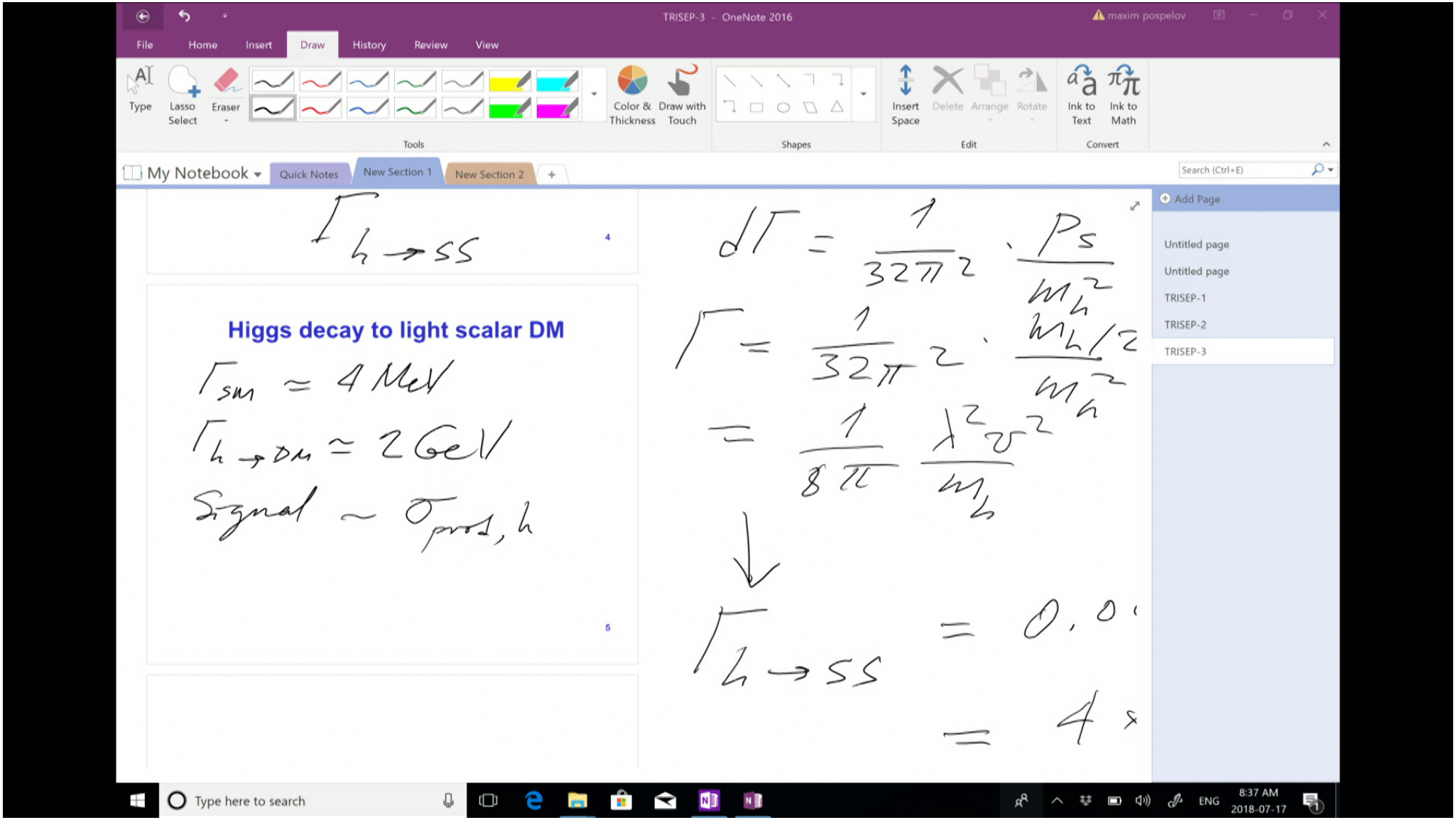

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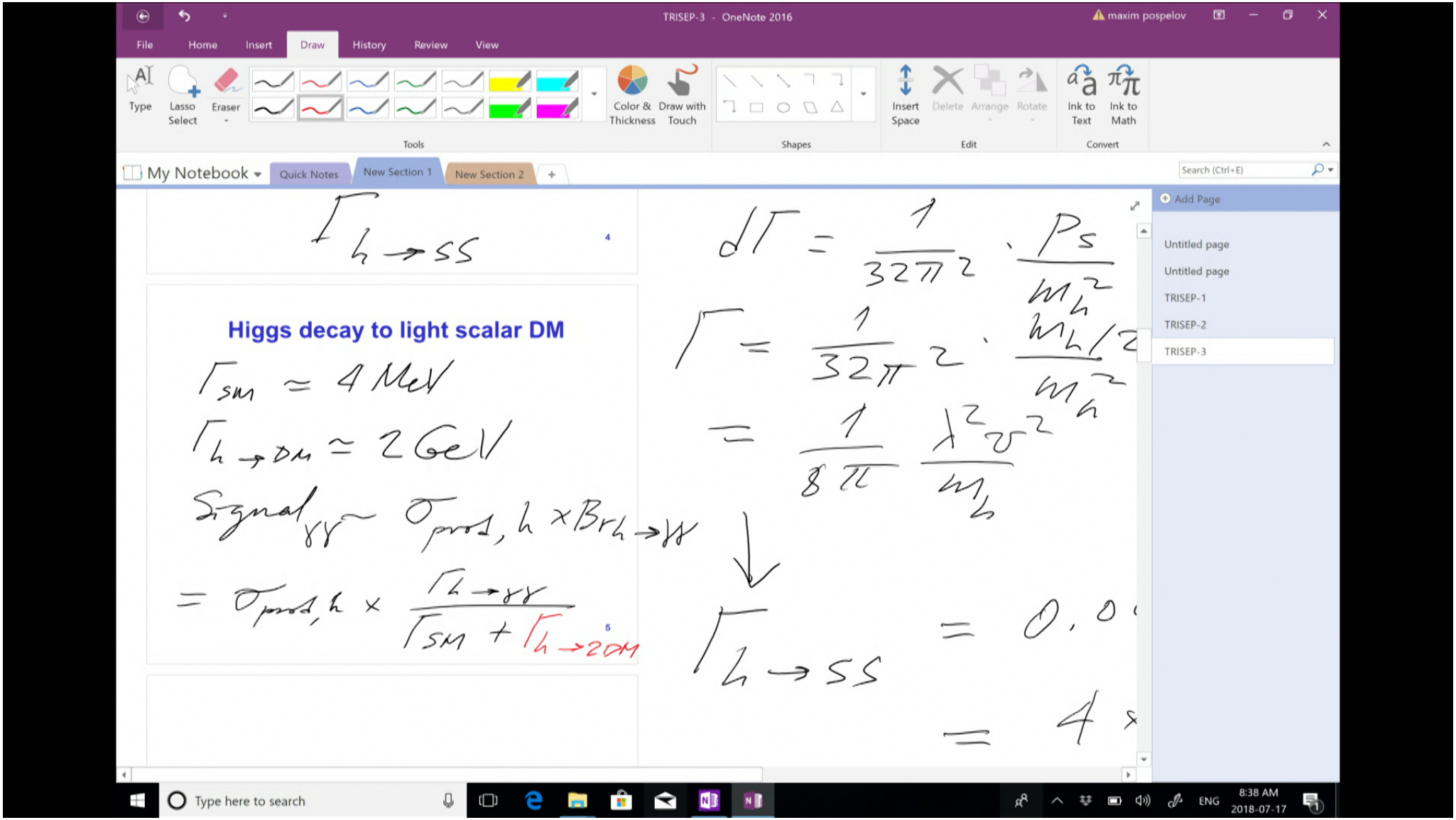

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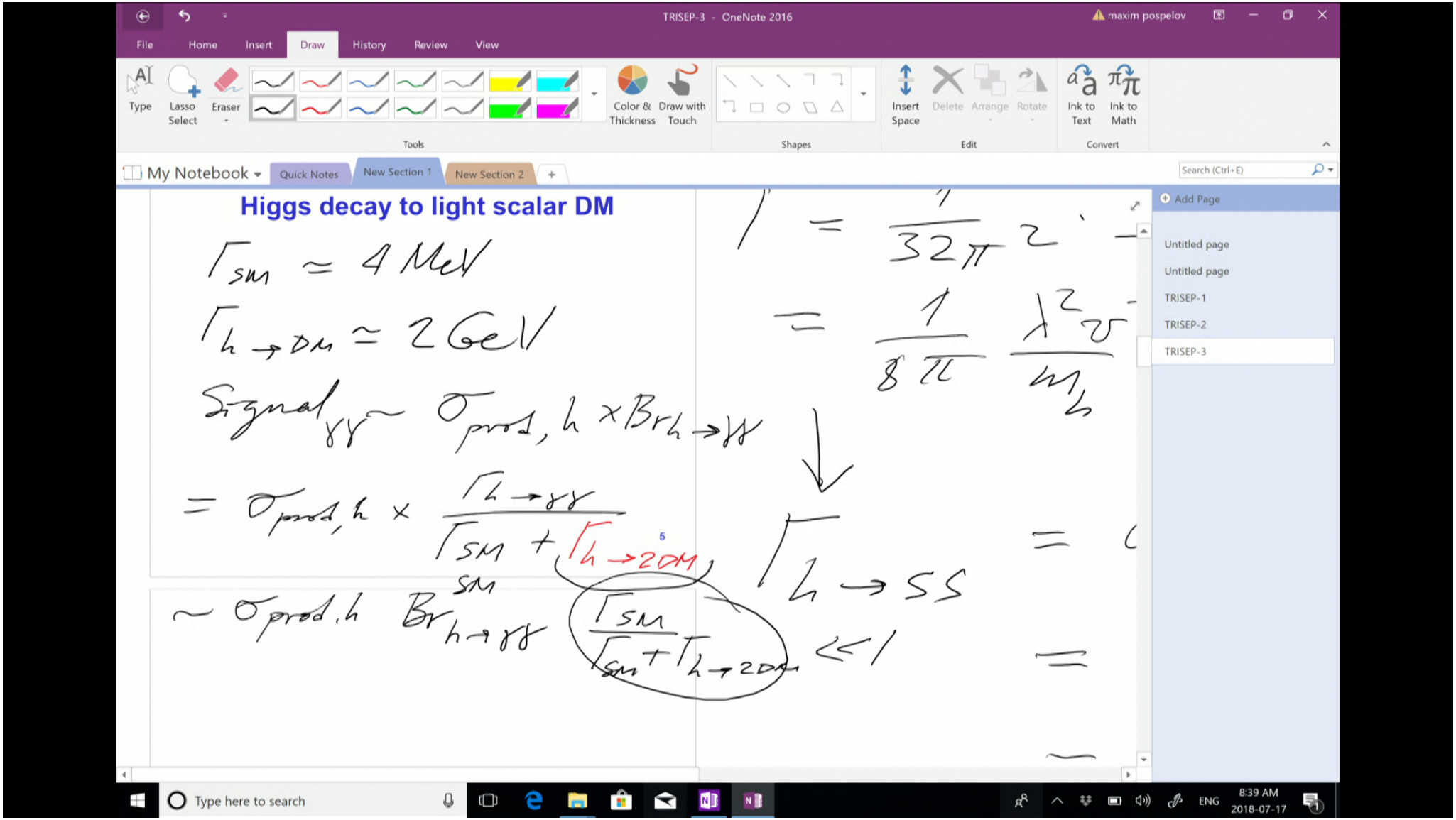

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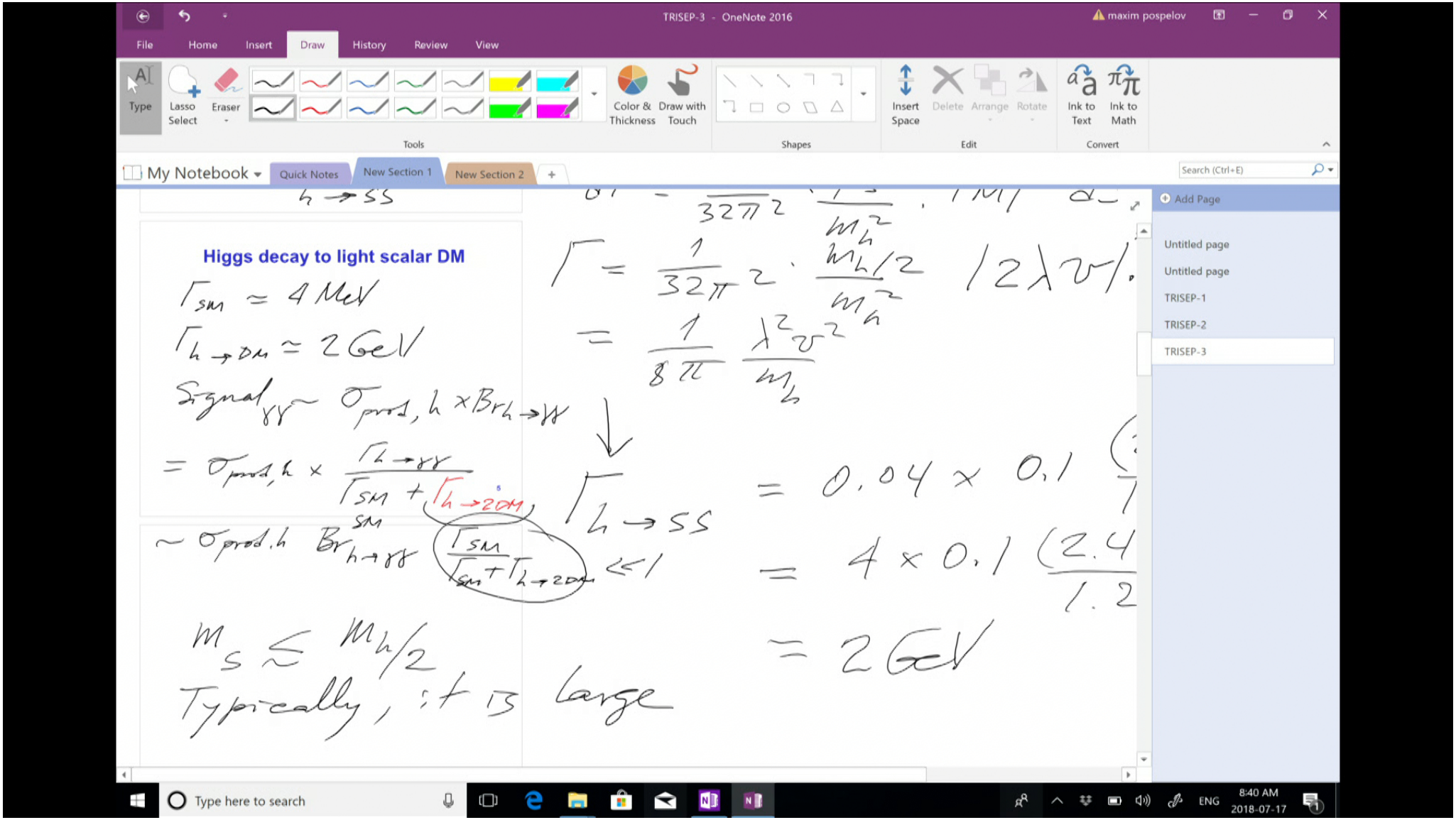

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Higgs decay to light scalar DM
$= \pi \frac{(1.25)^4}{16} \cdot 10^8 \times 10^{-10} \times 25$
$\sim \frac{\pi (1.25)^4}{16 \cdot 4} = \frac{3.16 \times 2.5}{64} \sim 0.1$
$\Gamma_{h \to ss}$
$\Gamma_{SM} = 4.2\,MeV$
$d\Gamma = \frac{1}{32\pi^2} \cdot \frac{P_s}{m_h^2} \cdot |M|^2 d\Omega$
$\Gamma = \frac{1}{32\pi^2} \cdot \frac{m_h/2}{m_h^2} |2\lambda v|^2 \cdot 2\pi$
$= \frac{1}{8\pi} \frac{\lambda^2 v^2}{m_h}$
$\Gamma_{h \to ss} = 0.04 \times 0.1 \frac{(246)^2}{125}\,GeV$
$= 4 \times 0.1 \frac{(2.46)^2}{1.25}\,GeV$
$= 2\,GeV$
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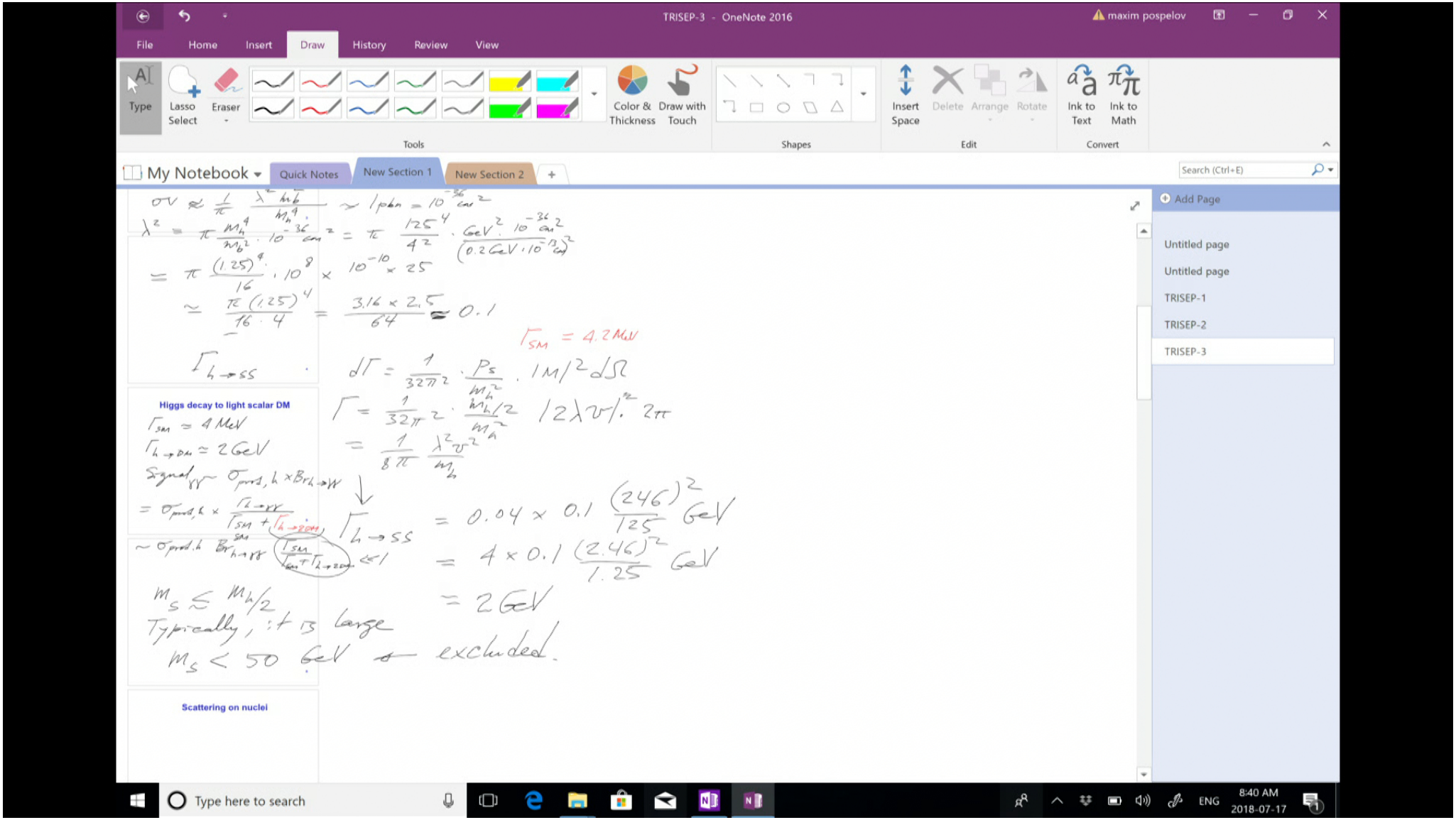

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Higgs decay to light scalar DM
$\Gamma_{SM} \simeq 4\,MeV$
$\Gamma_{h \to DM} \simeq 2\,GeV$
$\Gamma_{h \to SS}$
$d\Gamma = \frac{1}{32\pi^2} \cdot \frac{P_S}{m_h^2}$
$\Gamma = \frac{1}{32\pi} \cdot \frac{m_h/2}{m_h^2}$
$= \frac{1}{8\pi} \frac{\lambda^2 v^2}{m_h}$
$\Gamma_{h \to SS} = 0.0$
$= 4$
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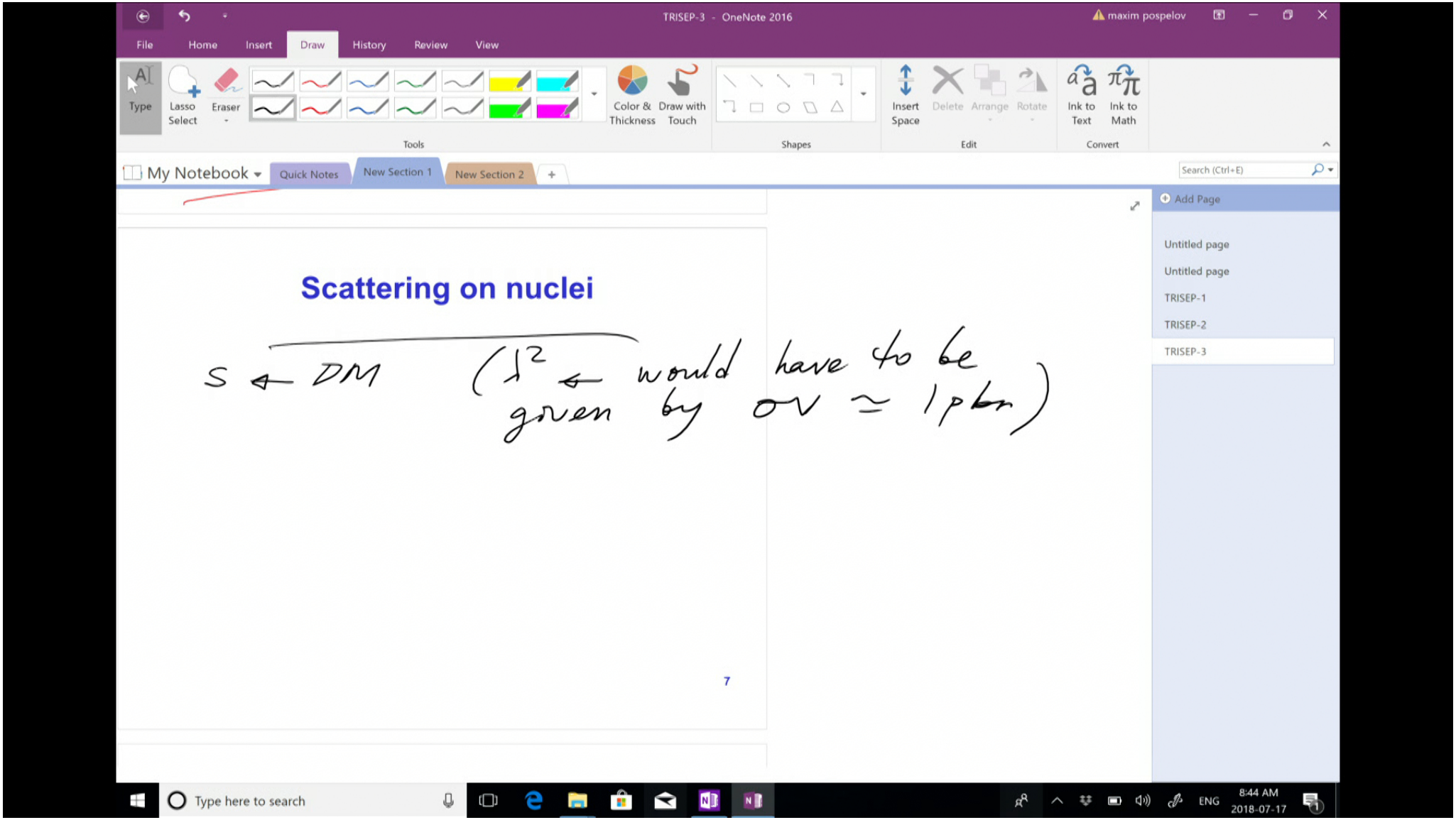

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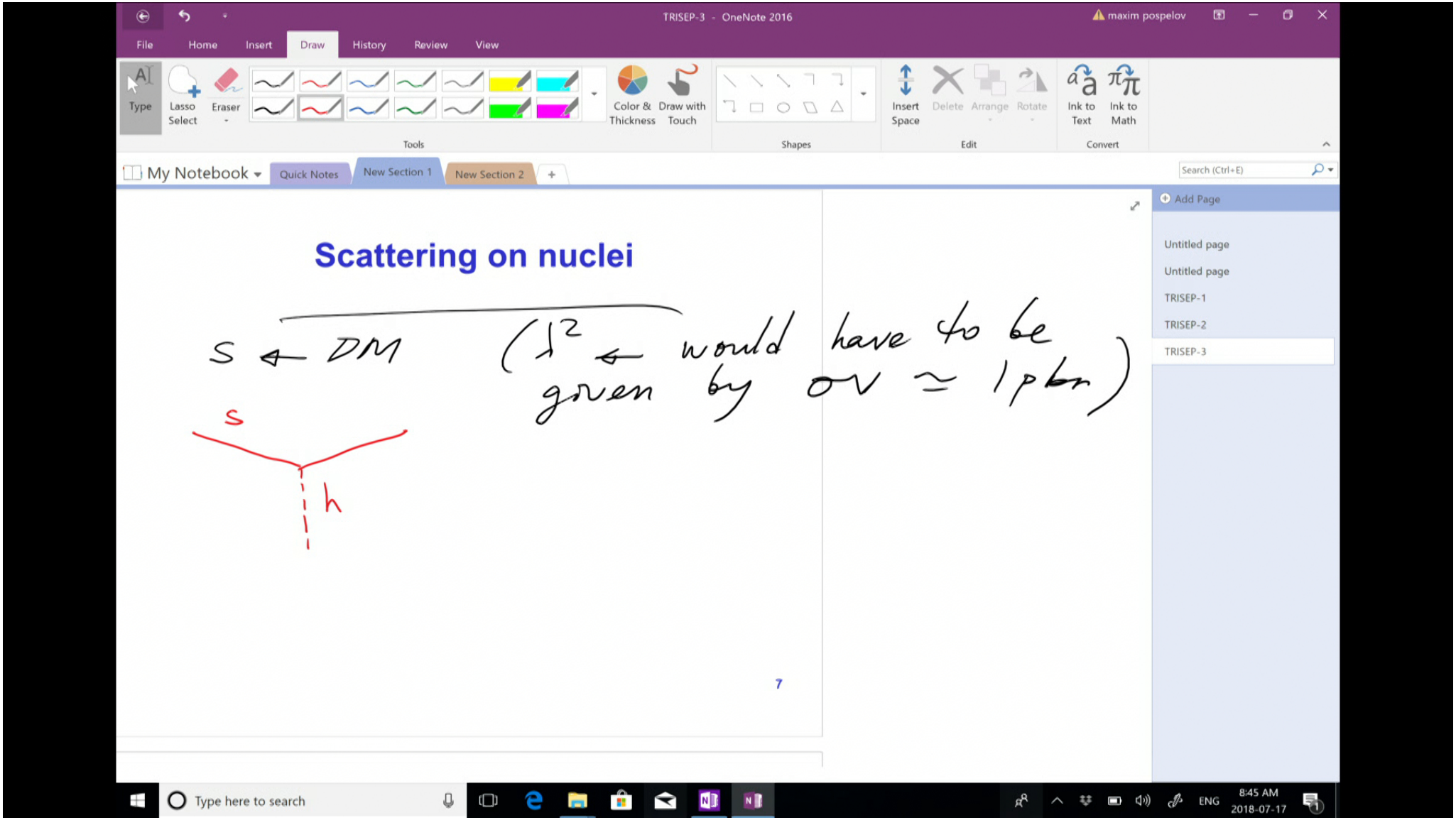

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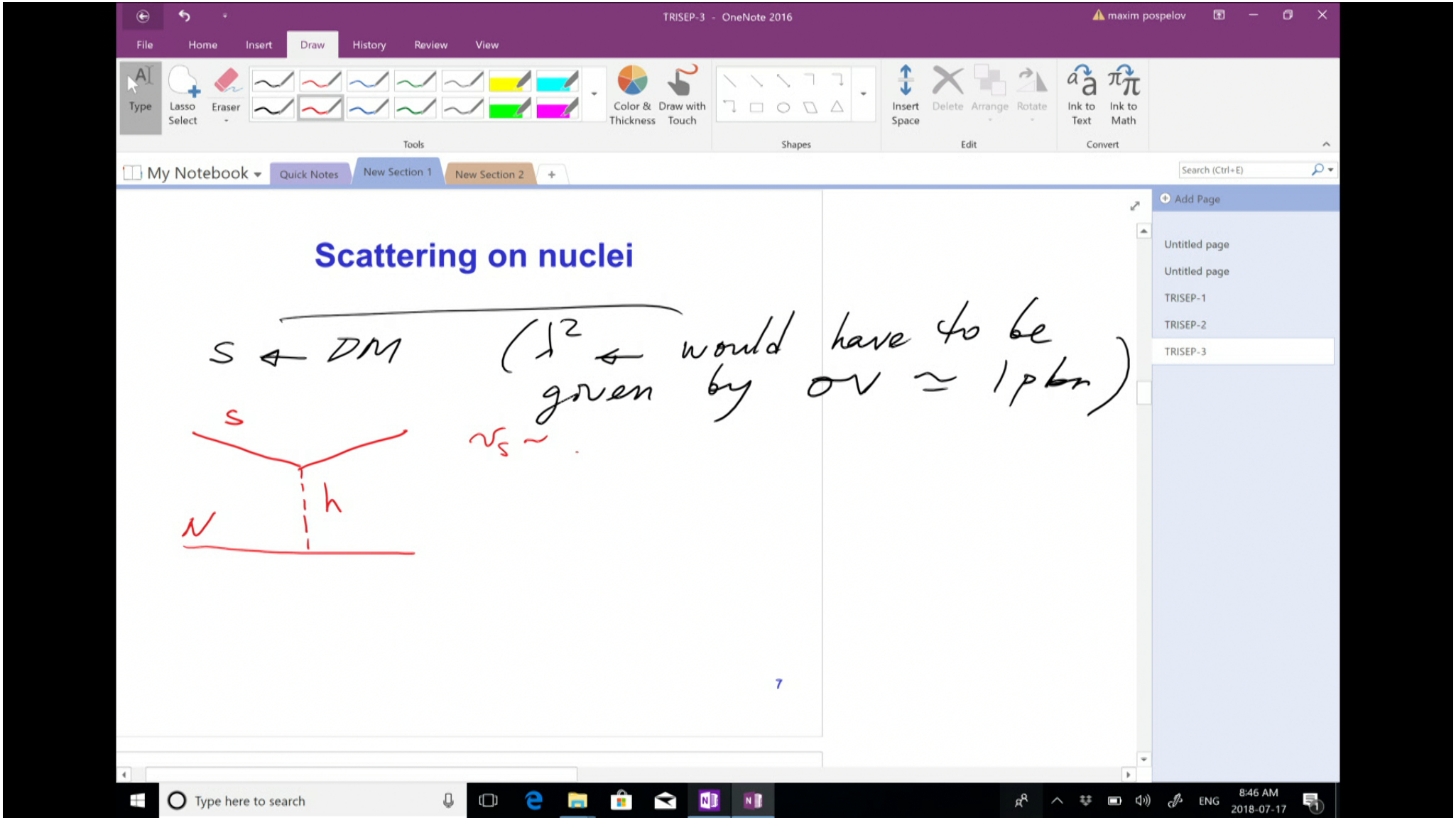

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TRISEP-1
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TRISEP-3
Scattering on nuclei
s ← DM (σ² ← would have to be given by ov ≃ 1pb)
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ENG
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2018-07-17


TRISEP-3 - OneNote 2016
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TRISEP-1
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TRISEP-3
Scattering on nuclei
s ← DM
(λ² ← would have to be given by σv ≃ 1 pb)
s
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ENG
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2018-07-17


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TRISEP-1
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TRISEP-3
Scattering on nuclei
S ← DM
(σ² ← would have to be given by σv ≃ 1 pb)
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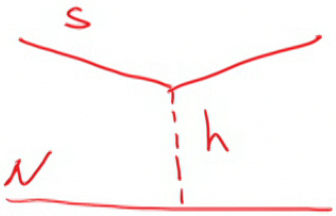
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TRISEP-1
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TRISEP-3

Scattering on nuclei

$S \leftarrow DM$ ($\lambda^2 \leftarrow$ would have to be given by $\sigma v \simeq 1\,pb$)



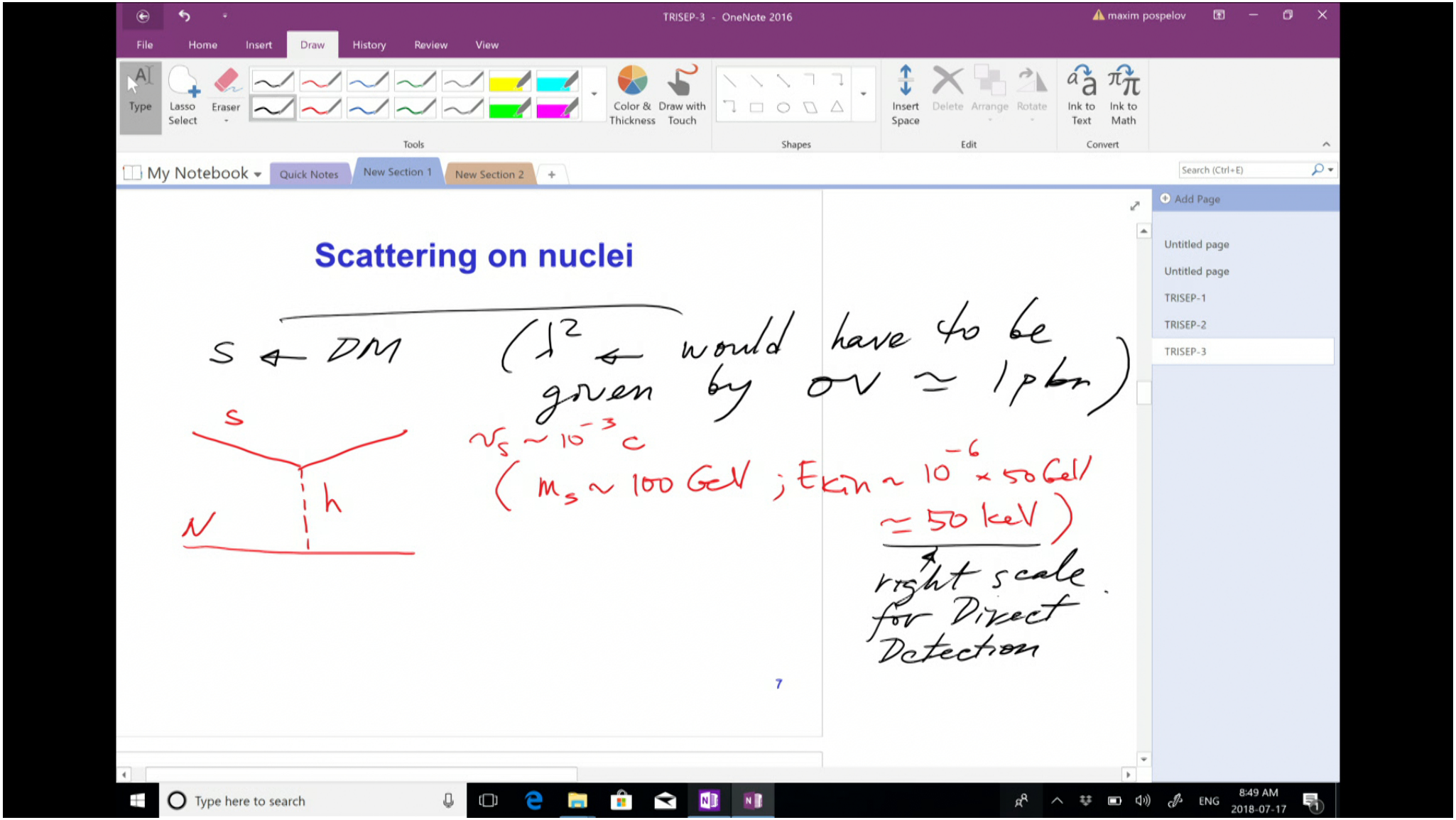
$v_S \sim 10^{-3} c$

($m_S \sim 100\,GeV$; $E_{kin} \sim 10^{-6} \times 50\,GeV \simeq 50\,keV$)

7

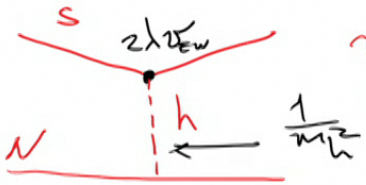
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TRISEP-1
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TRISEP-3
Scattering on nuclei
S ← DM
(σ² ← would have to be given by σv ≃ 1 pbn)
s
h
N
v_s ~ 10⁻³ c
(m_s ~ 100 GeV ; E_kin ~ 10⁻⁶ × 50 GeV ≃ 50 keV)
right scale for Direct Detection
7
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Scattering on nuclei

$S \leftarrow DM$ ($\lambda^2 \leftarrow$ would have to be given by $\sigma v \simeq 1\,pb$)



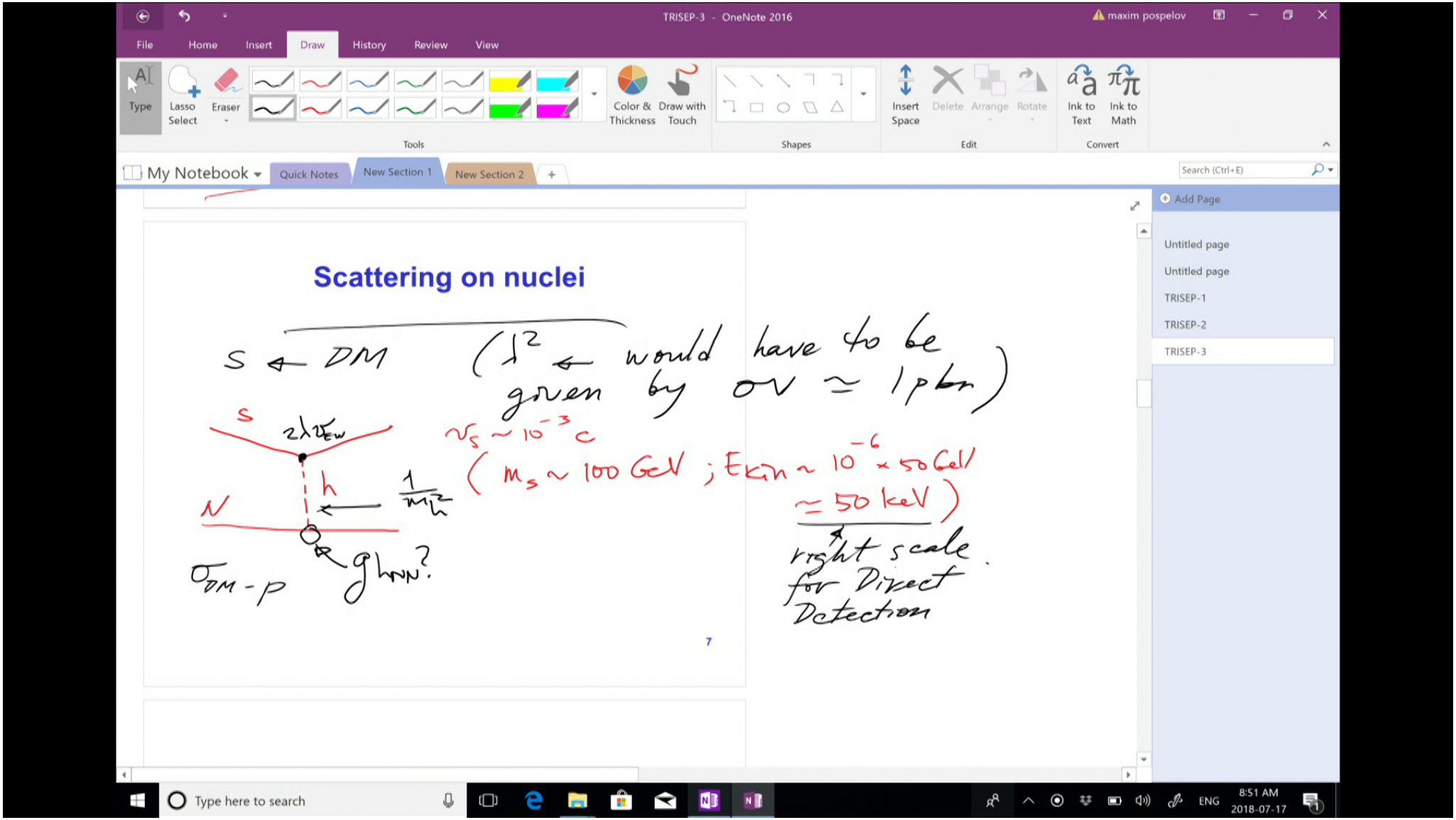
$v_S \sim 10^{-3} c$

($m_S \sim 100$ GeV ; $E_{kin} \sim 10^{-6} \times 50$ GeV $\simeq 50$ keV)

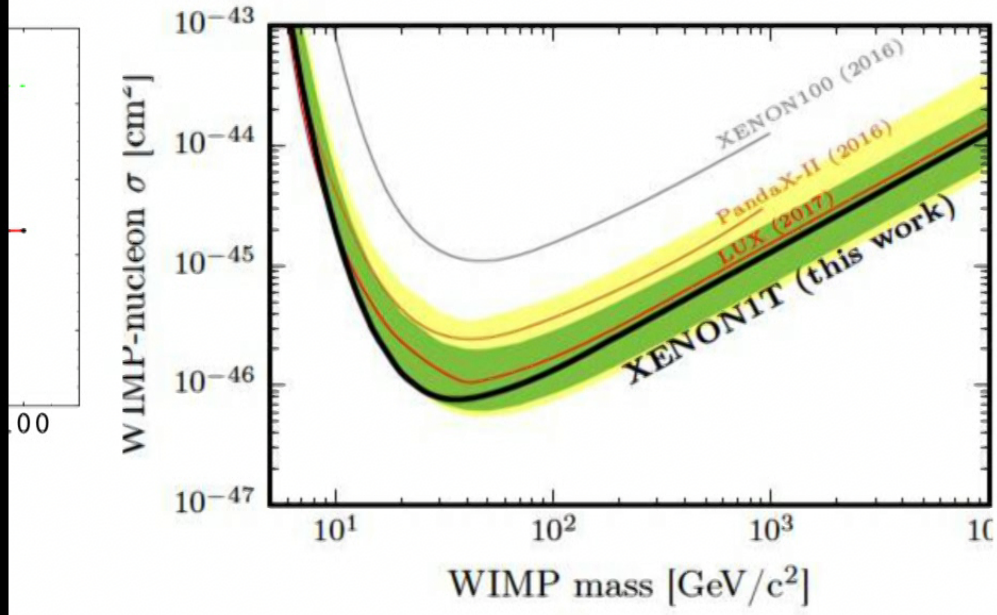
right scale for Direct Detection.

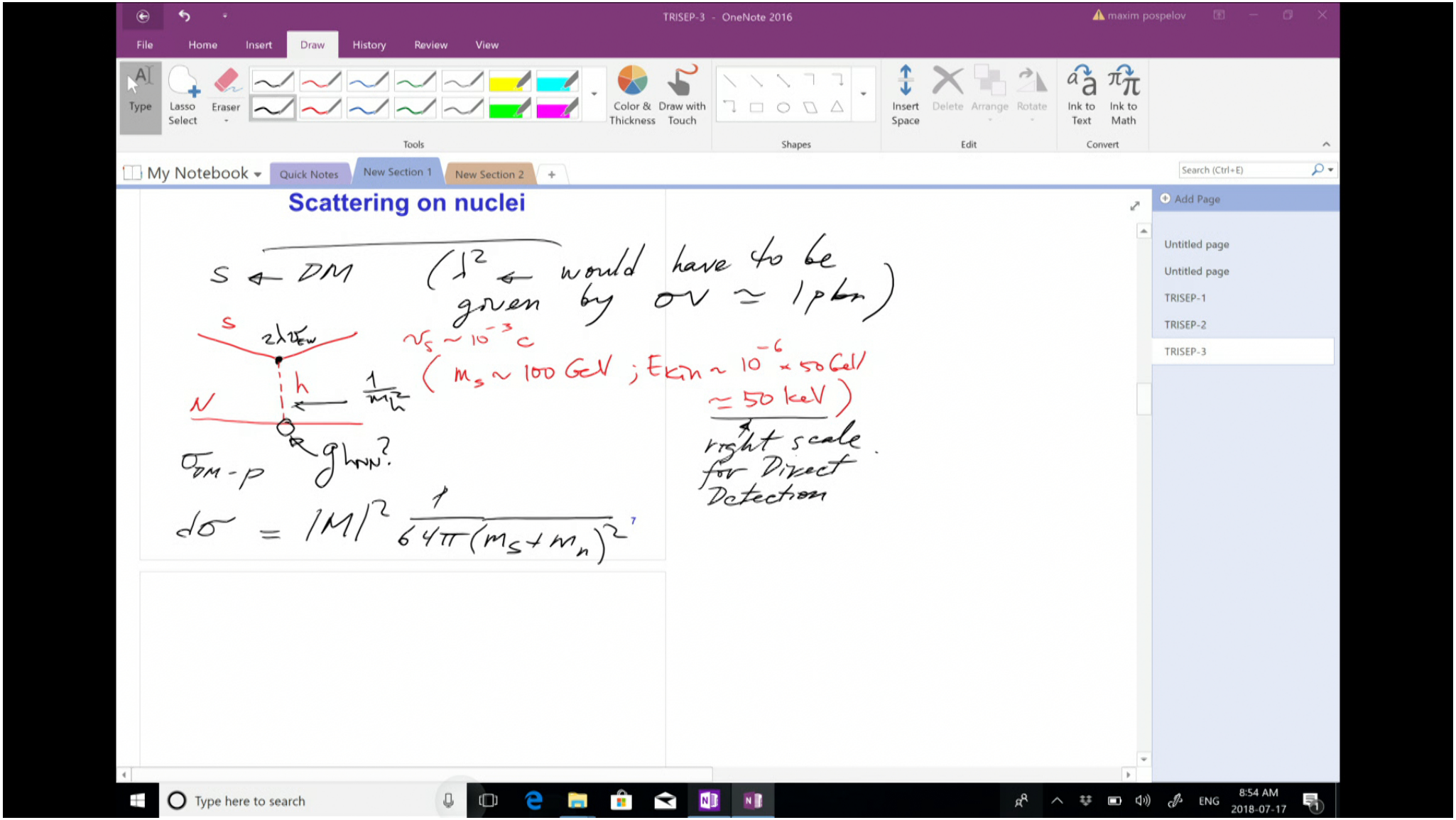
σ_{DM-p}

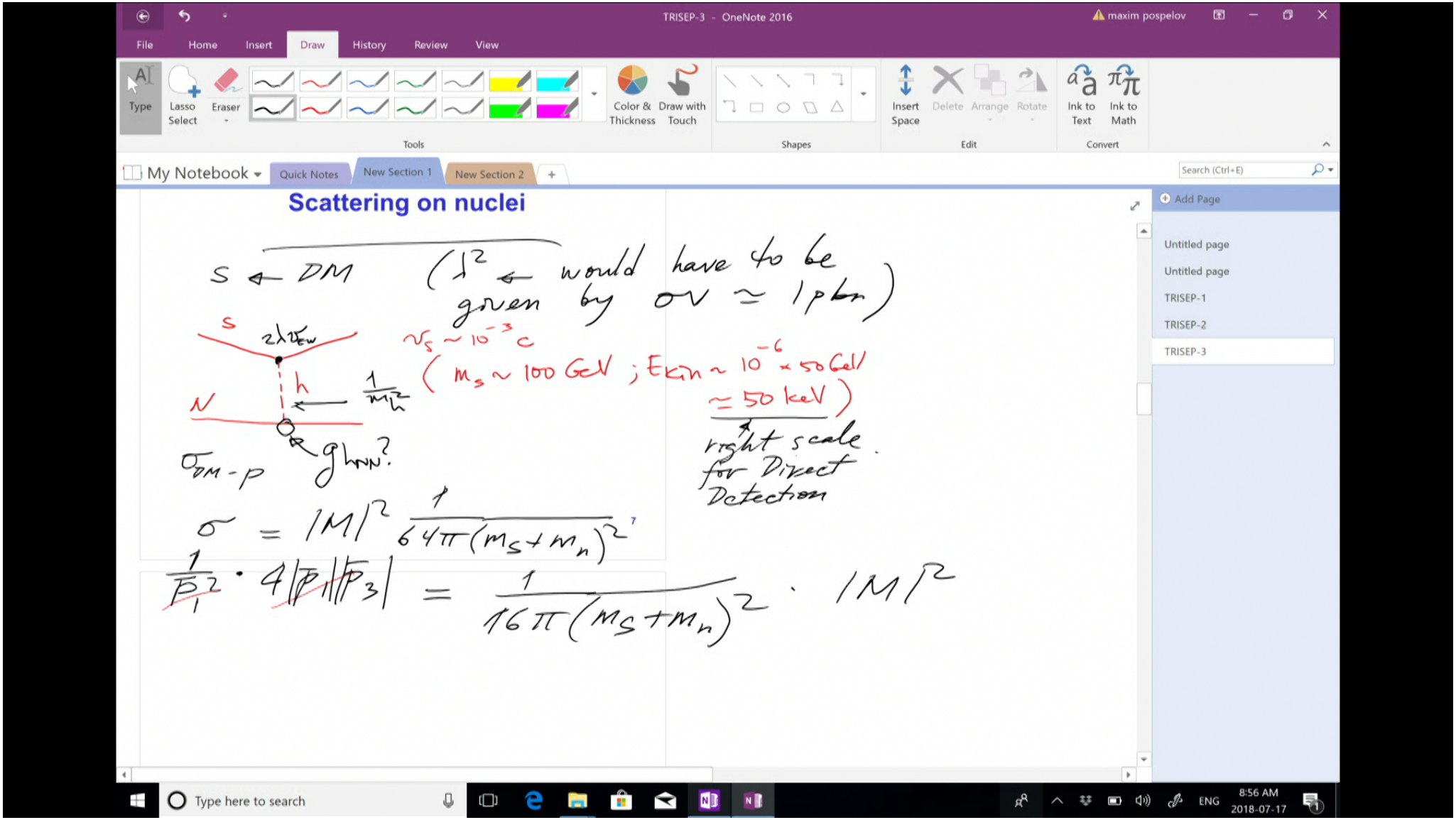
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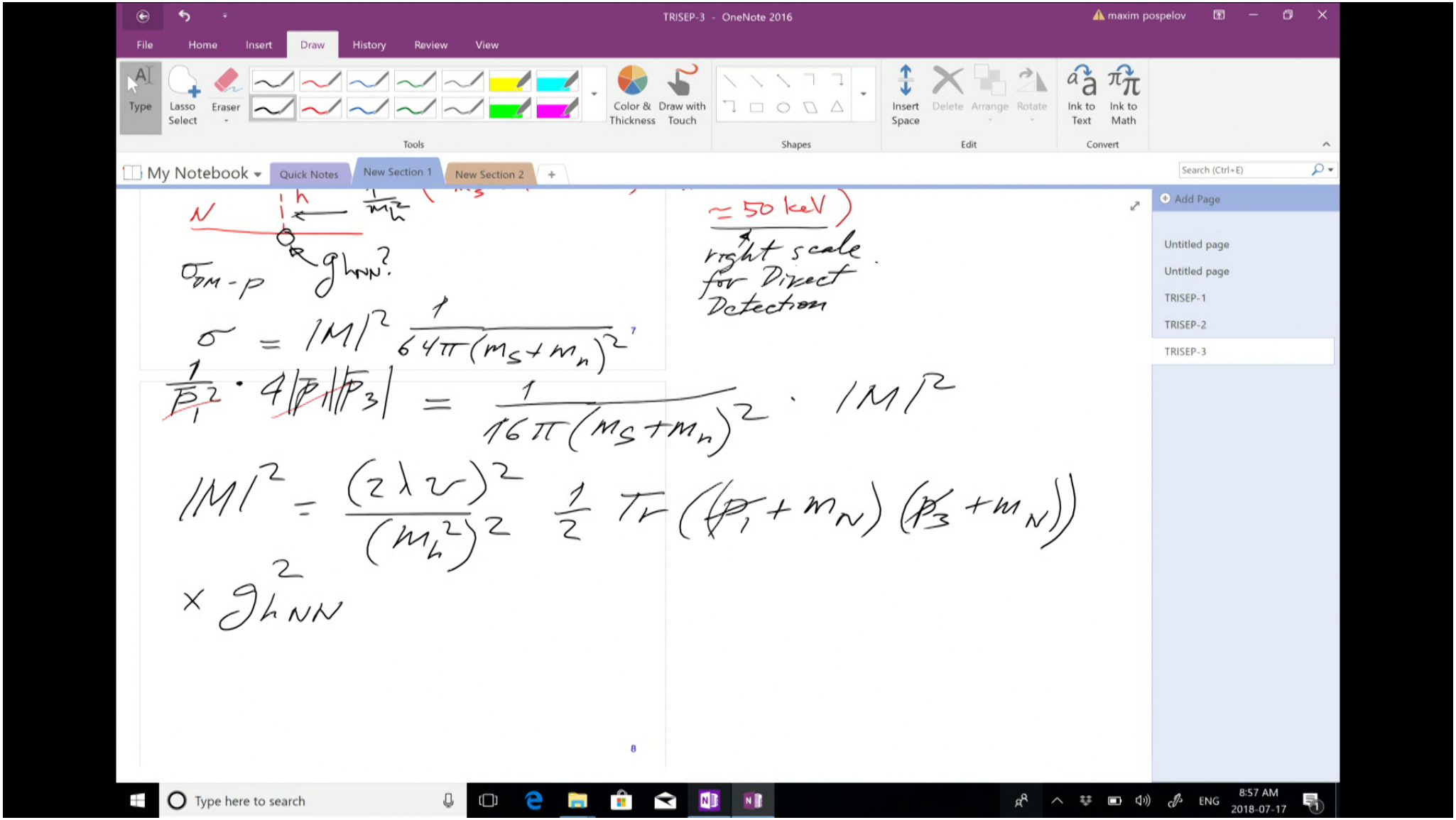

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Scattering on nuclei
S ← DM
(λ² ← would have to be given by σv ≃ 1pb)
s
2λ²_EW
h
1/m_h²
N
g_hNN?
σ_DM-p
v_s ~ 10⁻³ c
(m_s ~ 100 GeV ; E_kin ~ 10⁻⁶ × 50 GeV ≃ 50 keV)
right scale for Direct Detection
7
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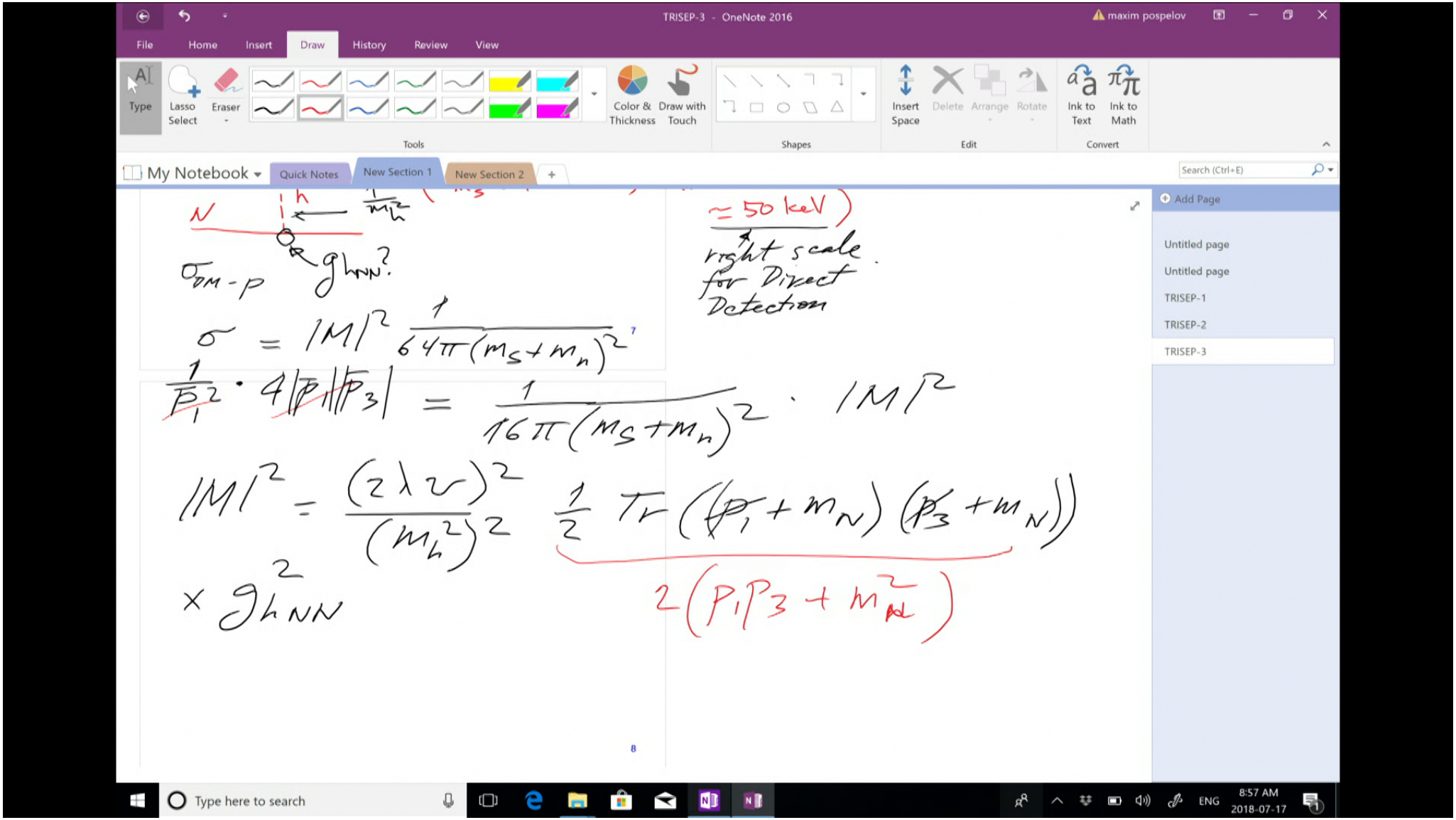
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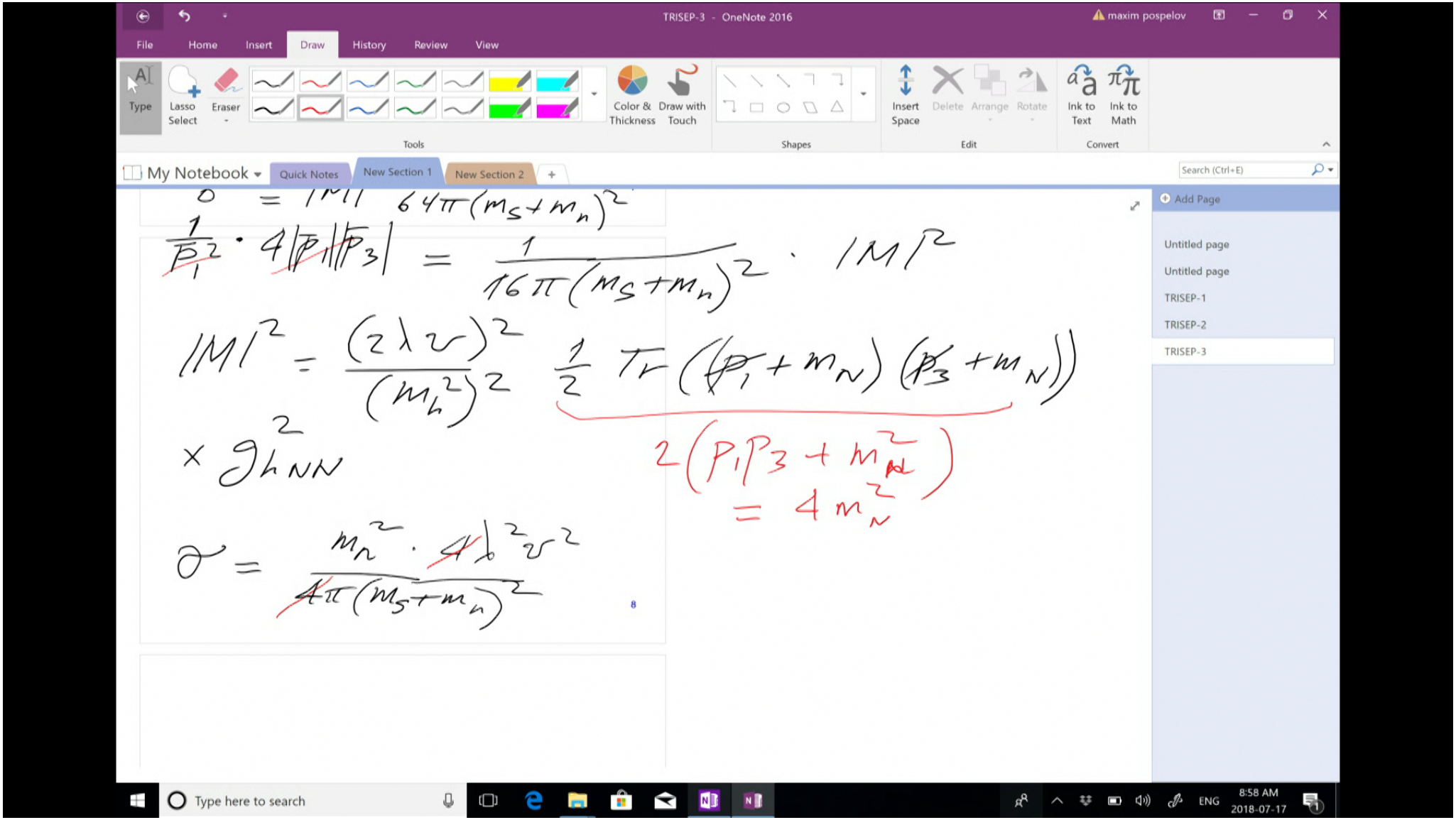


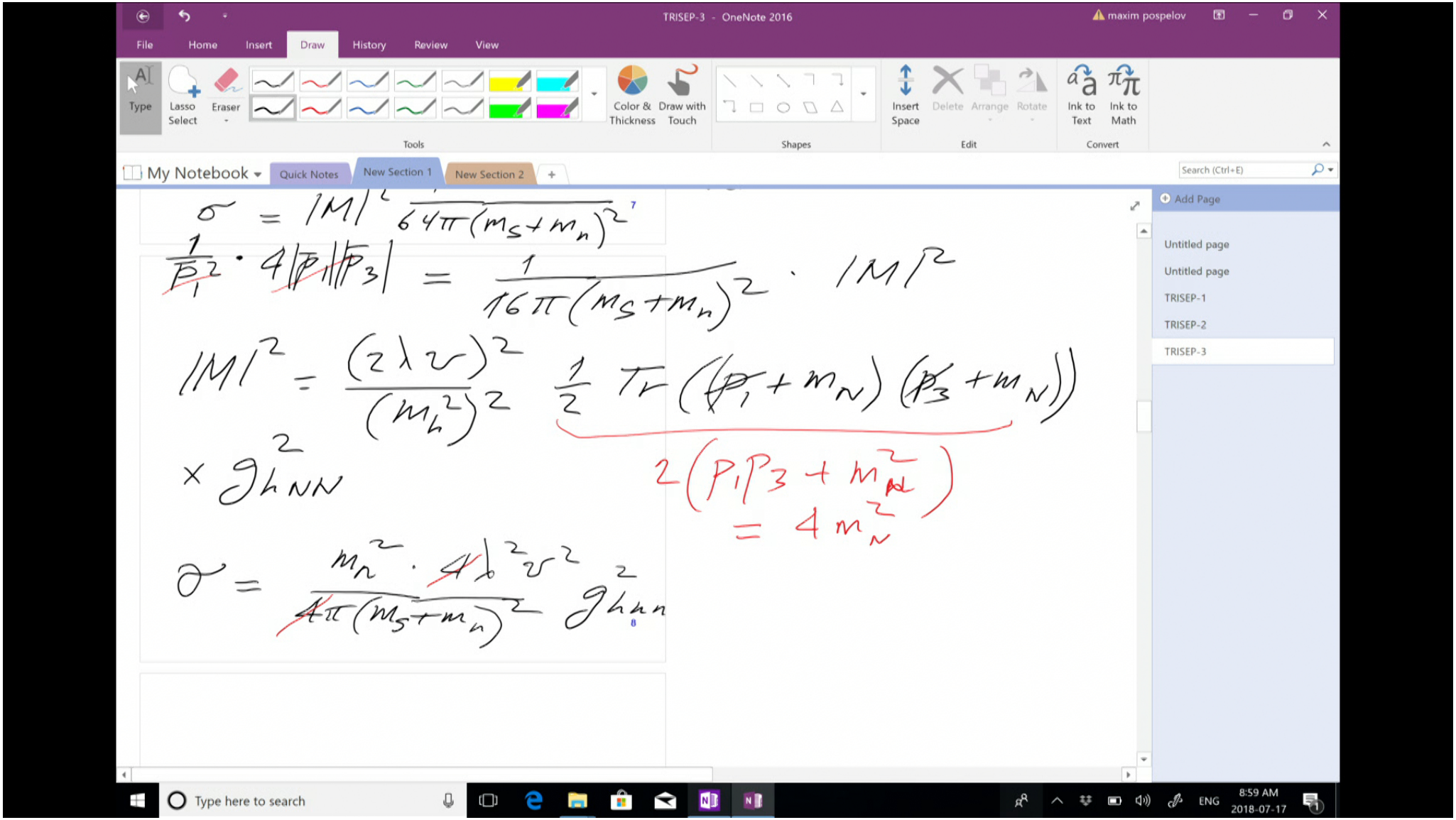

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Scattering on nuclei
S ← DM (λ² ← would have to be given by σv ≃ 1 pb)
S
2λ²v_EW
h
1/m_h²
N
g_hNN?
σ_DM-p
v_S ~ 10⁻³ c
(m_S ~ 100 GeV ; E_kin ~ 10⁻⁶ × 50 GeV ≃ 50 keV)
right scale for Direct Detection.
dσ = |M|² 1/(64π(m_S + m_n)²)
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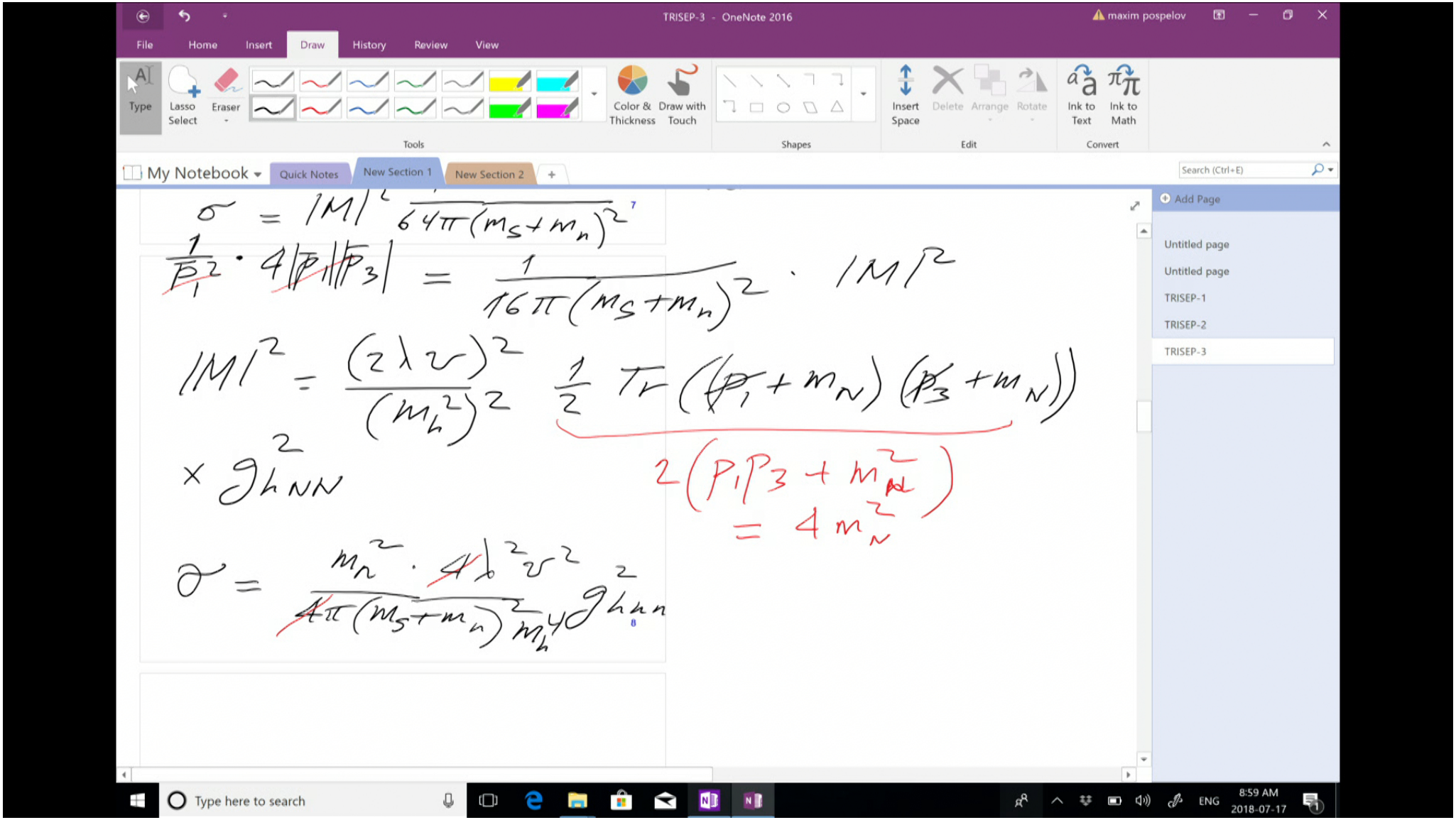

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Scattering on nuclei
S ← DM (λ² ← would have to be given by σv ≃ 1 pb)
s
2λ²v_EW
h
1/m_h²
N
g_hNN?
σ_DM-p
v_S ~ 10⁻³ c
(m_S ~ 100 GeV ; E_kin ~ 10⁻⁶ × 50 GeV ≃ 50 keV)
right scale for Direct Detection.
σ = |M|² 1/(64π(m_S+m_n)²)
1/E₁² · 4|p||p₃| = 1/(16π(m_S+m_n)²) · |M|²
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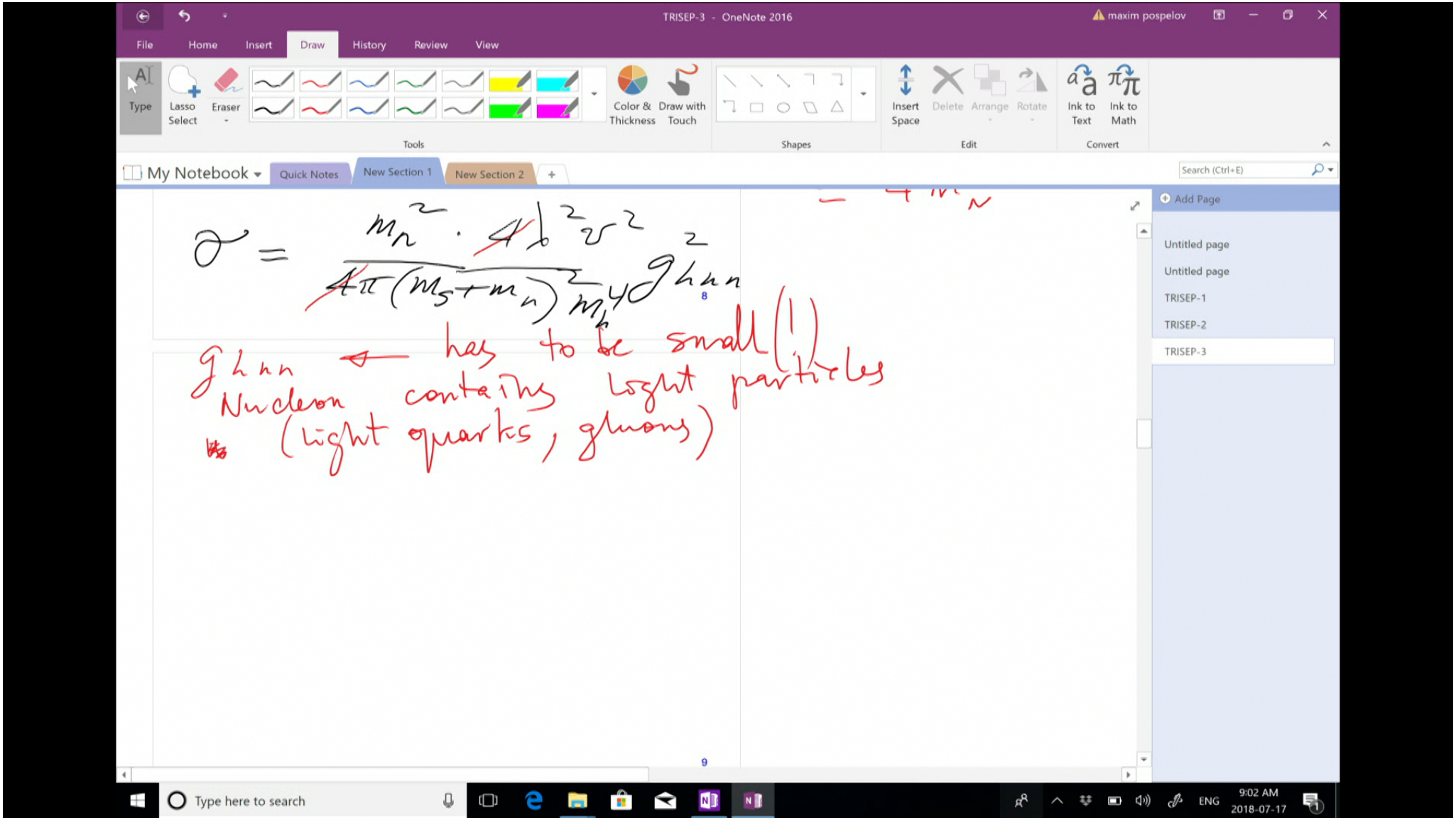

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≃ 50 keV
right scale for Direct Detection
σ_{DM-p}
g_{hNN}?
$\sigma = |M|^2 \frac{1}{64\pi(m_S+m_n)^2}$
$\frac{1}{E_1^2} \cdot 4|\vec{p}||\vec{p}_3| = \frac{1}{16\pi(m_S+m_n)^2} \cdot |M|^2$
$|M|^2 = \frac{(2\lambda v)^2}{(m_h^2)^2} \frac{1}{2} Tr((\not{p}_1 + m_N)(\not{p}_3 + m_N))$
$\times g_{hNN}^2$
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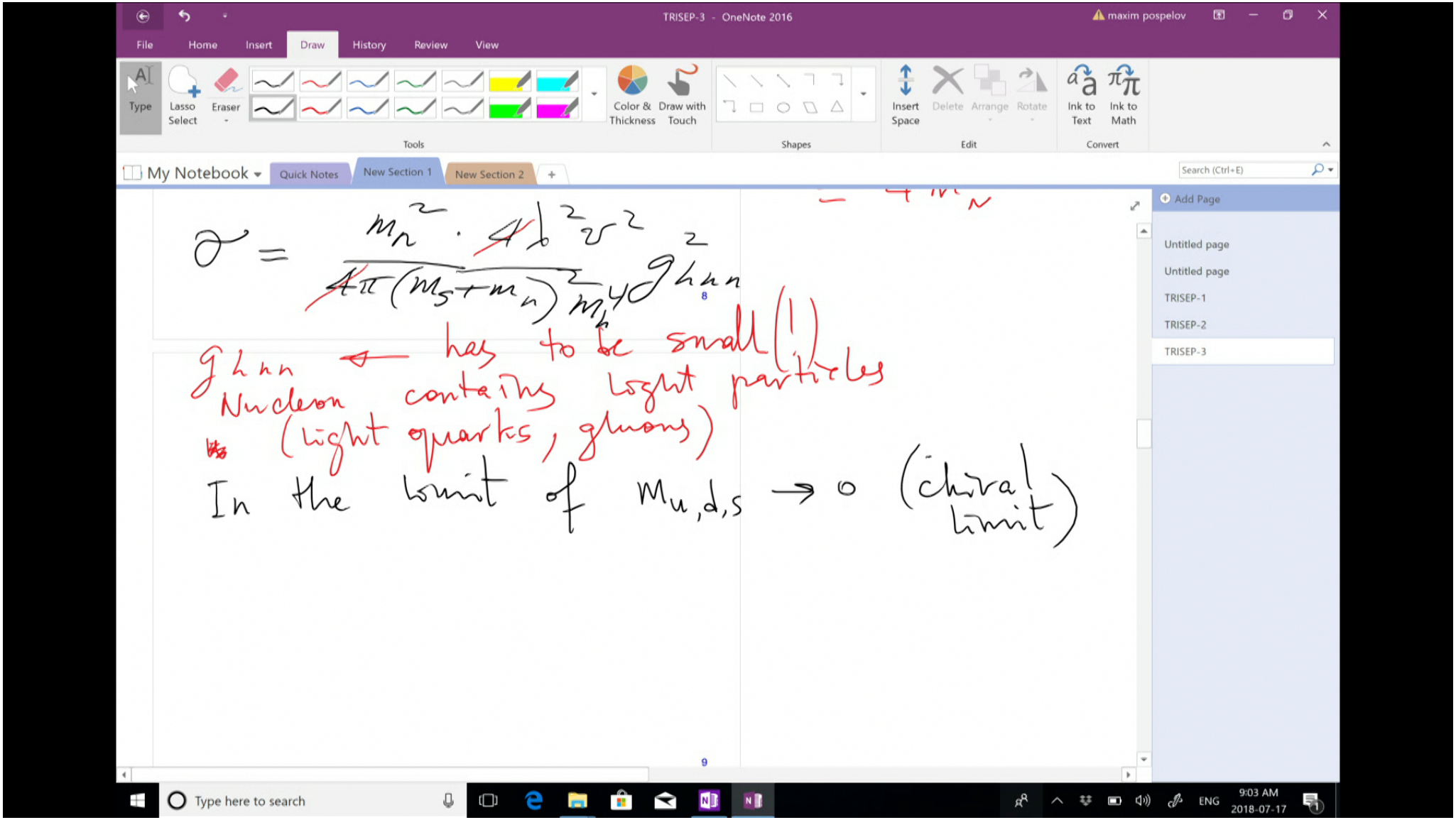

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≃ 50 keV
right scale for Direct Detection
σ_{DM-p}
g_{hNN}?
$\sigma = |M|^2 \frac{1}{64\pi(m_S+m_n)^2}$
$\frac{1}{E_1^2} \cdot 4|\vec{p}||\vec{p}_3| = \frac{1}{16\pi(m_S+m_n)^2} \cdot |M|^2$
$|M|^2 = \frac{(2\lambda v)^2}{(m_h^2)^2} \frac{1}{2} Tr((\not{p}_1 + m_N)(\not{p}_3 + m_N))$
$2(p_1 p_3 + m_{DM}^2)$
$\times g_{hNN}^2$
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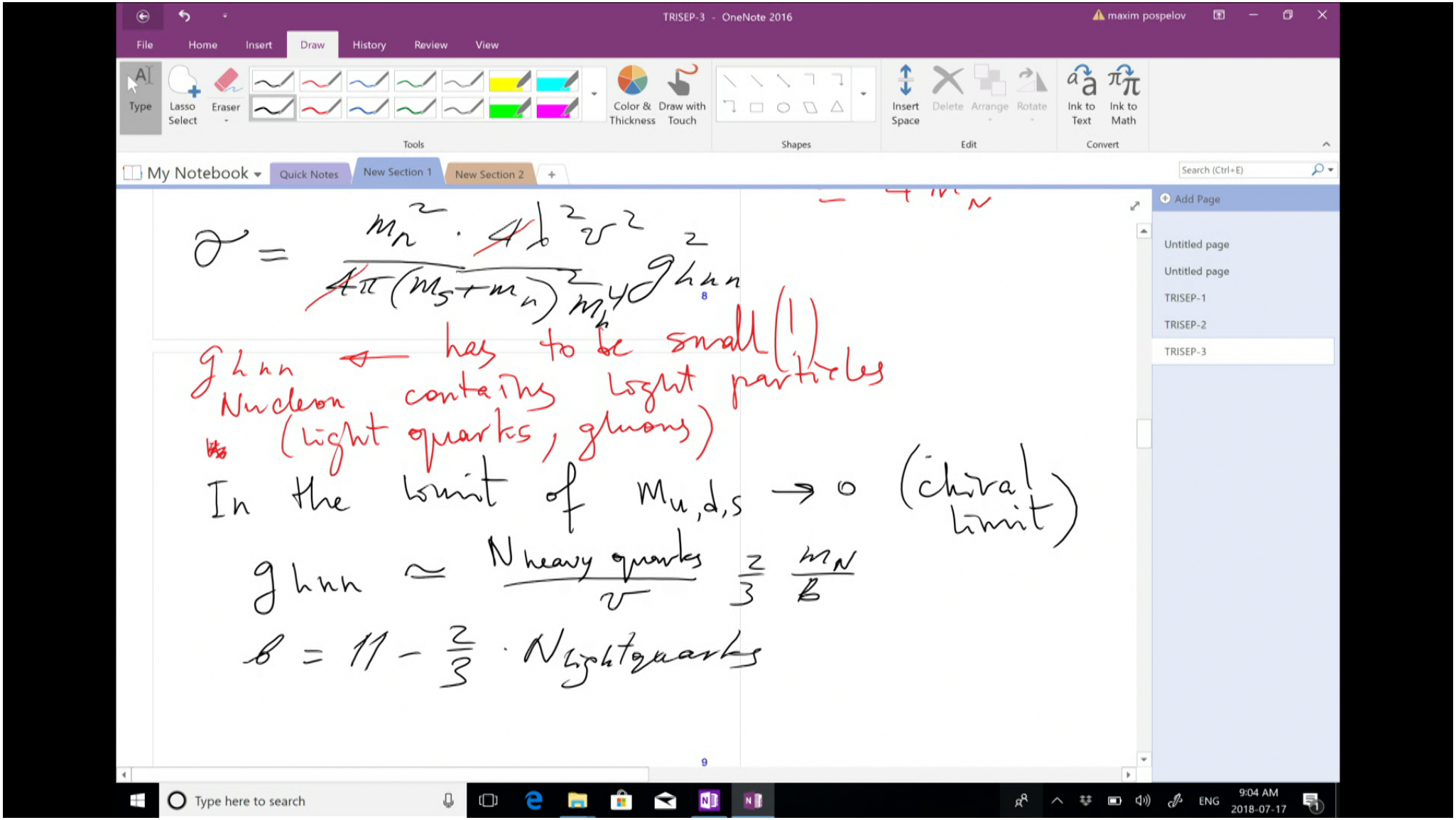

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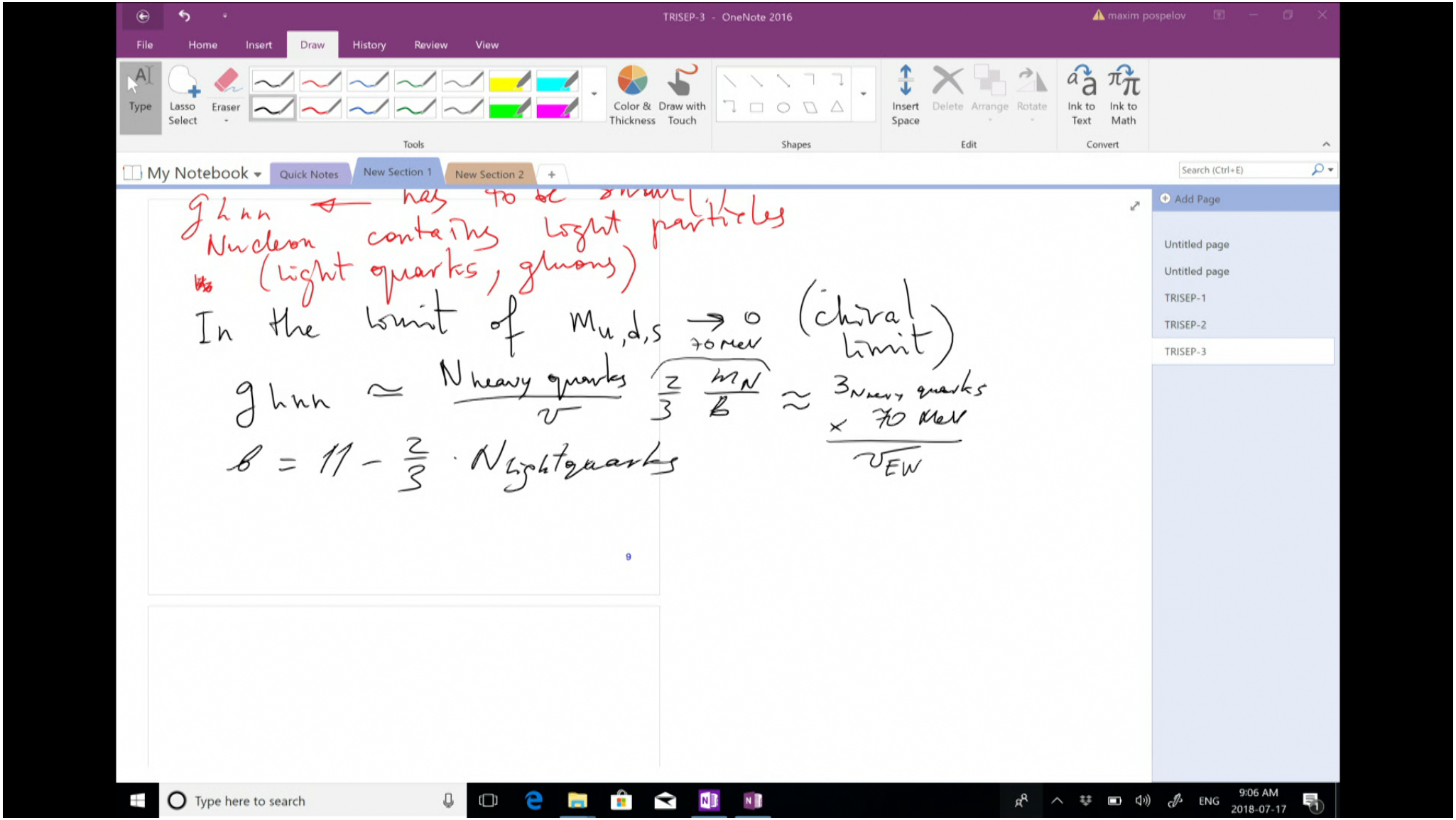

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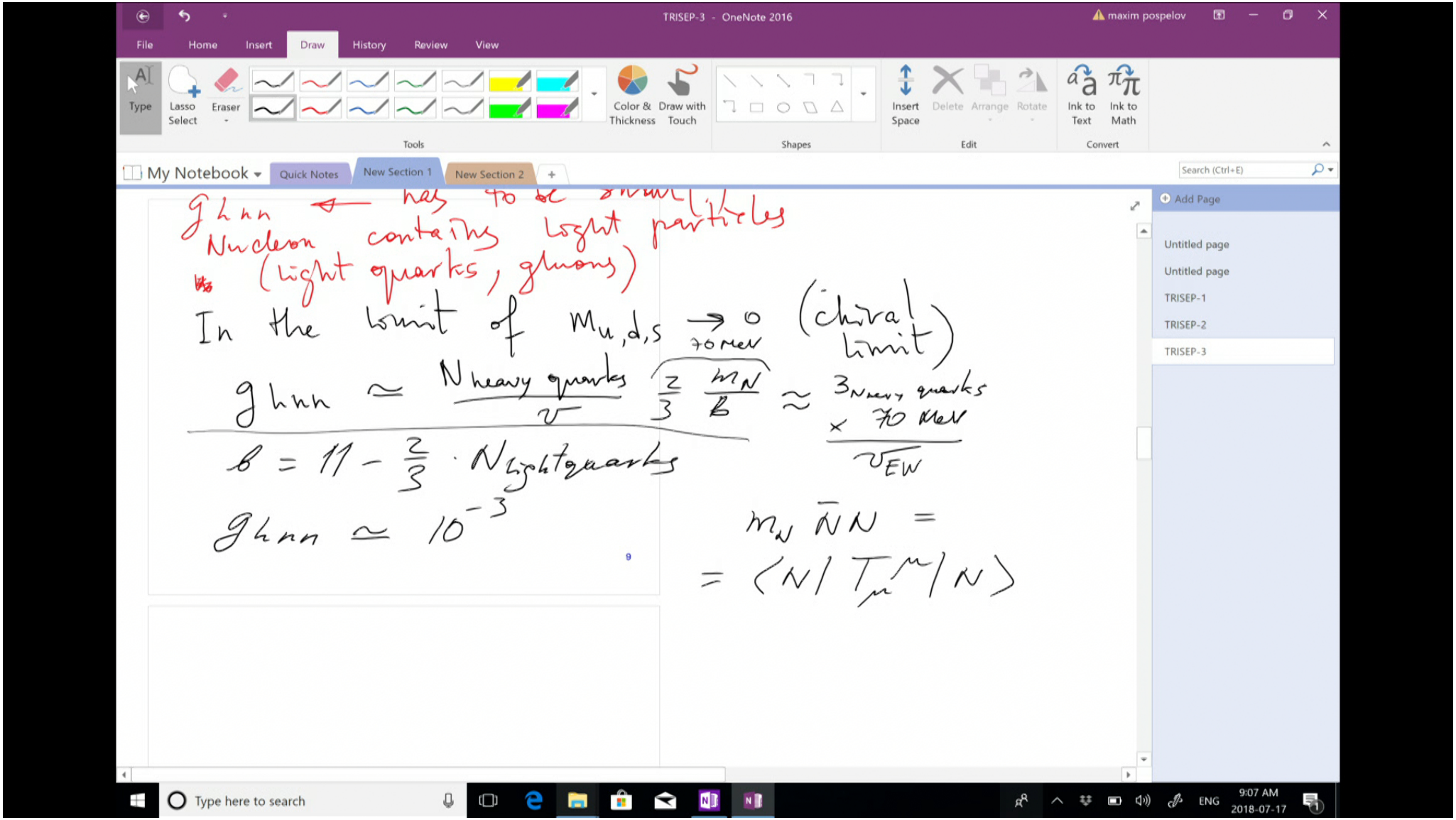

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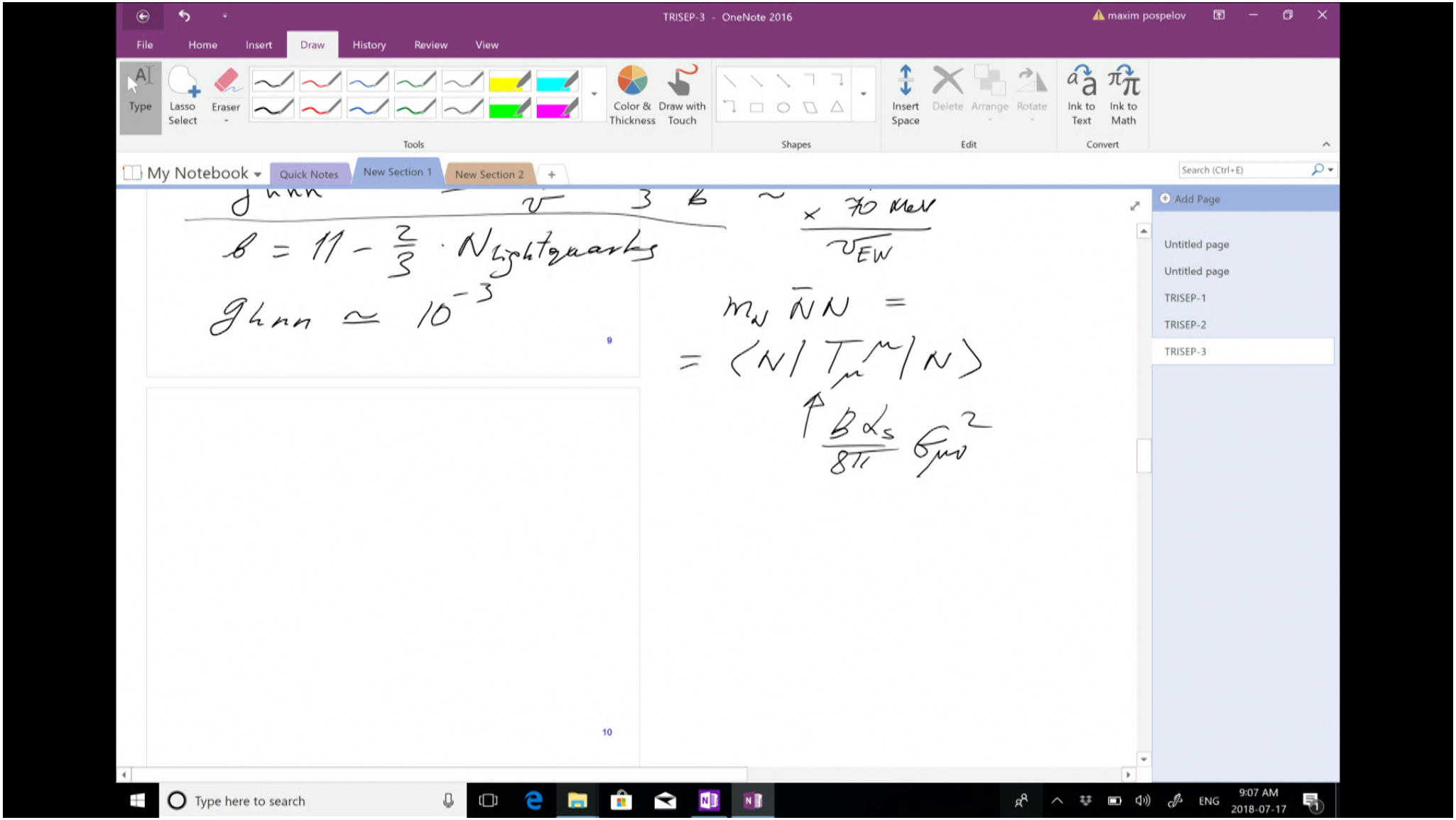

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$\sigma = \frac{m_n^2 \cdot 4 b^2 v^2}{4\pi (m_S + m_n)^2 m_h^4} g_{hnn}^2$
8
g_{hnn} ← has to be small (!)
Nucleon contains light particles
(light quarks, gluons)
9
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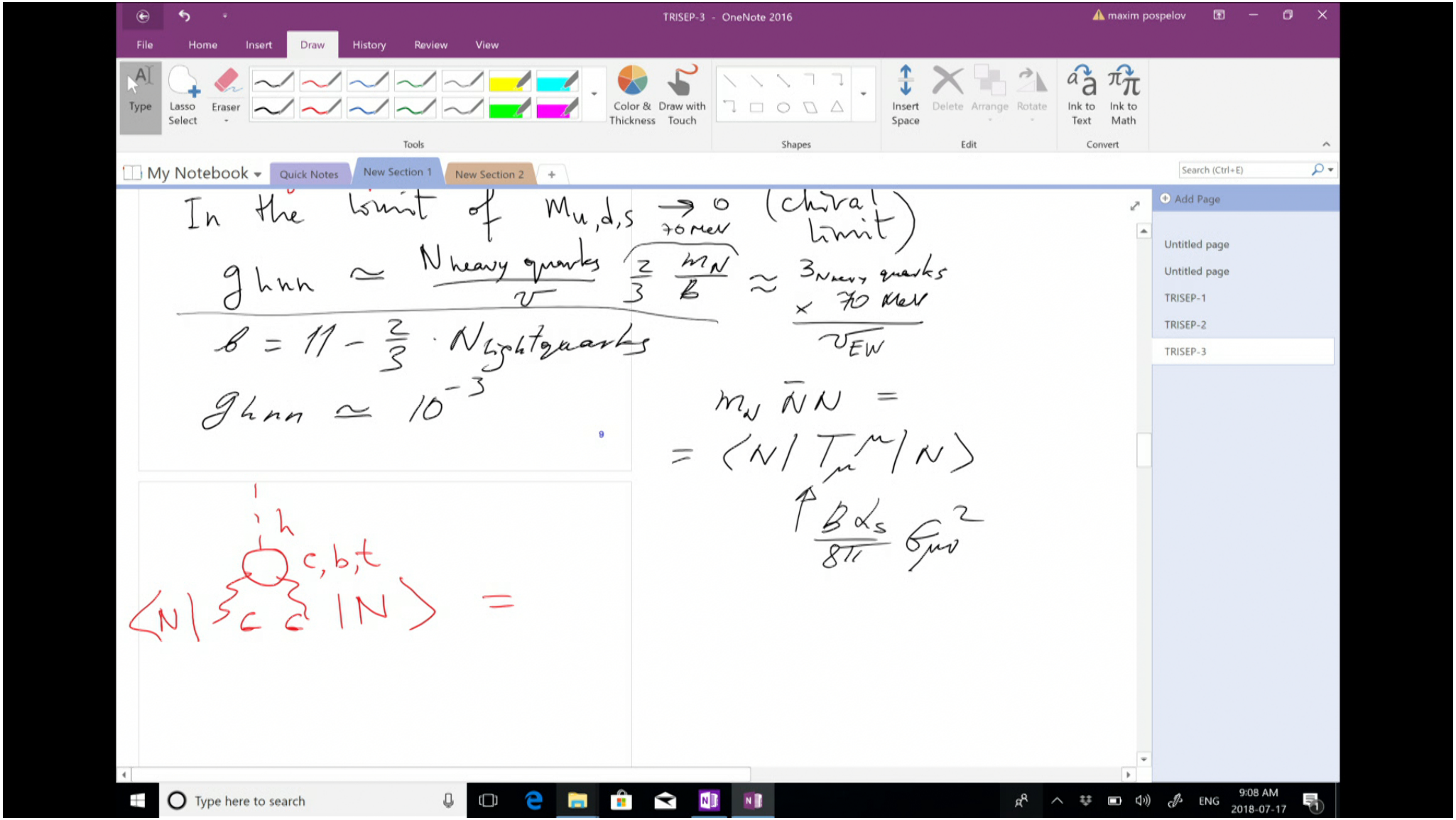

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$\sigma = \frac{m_n^2 \cdot 4b^2 v^2}{4\pi (m_S + m_n)^2 m_h^4} g_{hnn}^2$
8
g_{hnn} ← has to be small (!)
Nucleon contains light particles
(light quarks, gluons)
In the limit of $m_{u,d,s} \to 0$ (chiral limit)
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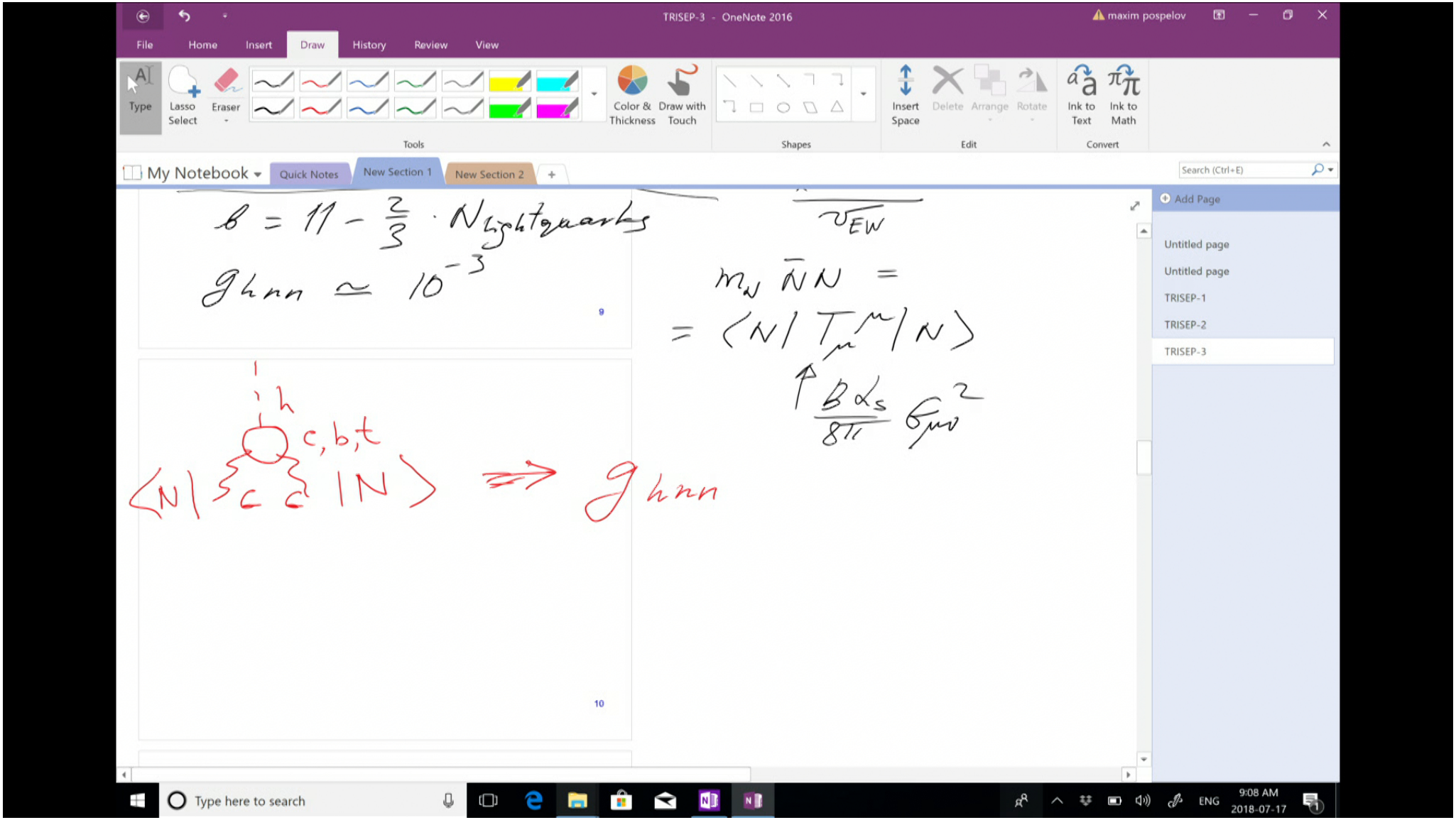

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$\gamma = \frac{m_n^2 \cdot 4 b^2 v^2}{4\pi (m_s + m_n)^2 m_h^4} g_{hnn}^2$
g_{hnn} ← has to be small (!)
Nucleon contains light particles
(light quarks, gluons)
In the limit of $m_{u,d,s} \to 0$ (chiral limit)
$g_{hnn} \simeq \frac{N_{heavy\ quarks}}{v} \frac{2}{3} \frac{m_N}{b}$
$b = 11 - \frac{2}{3} \cdot N_{light\ quarks}$
8
9
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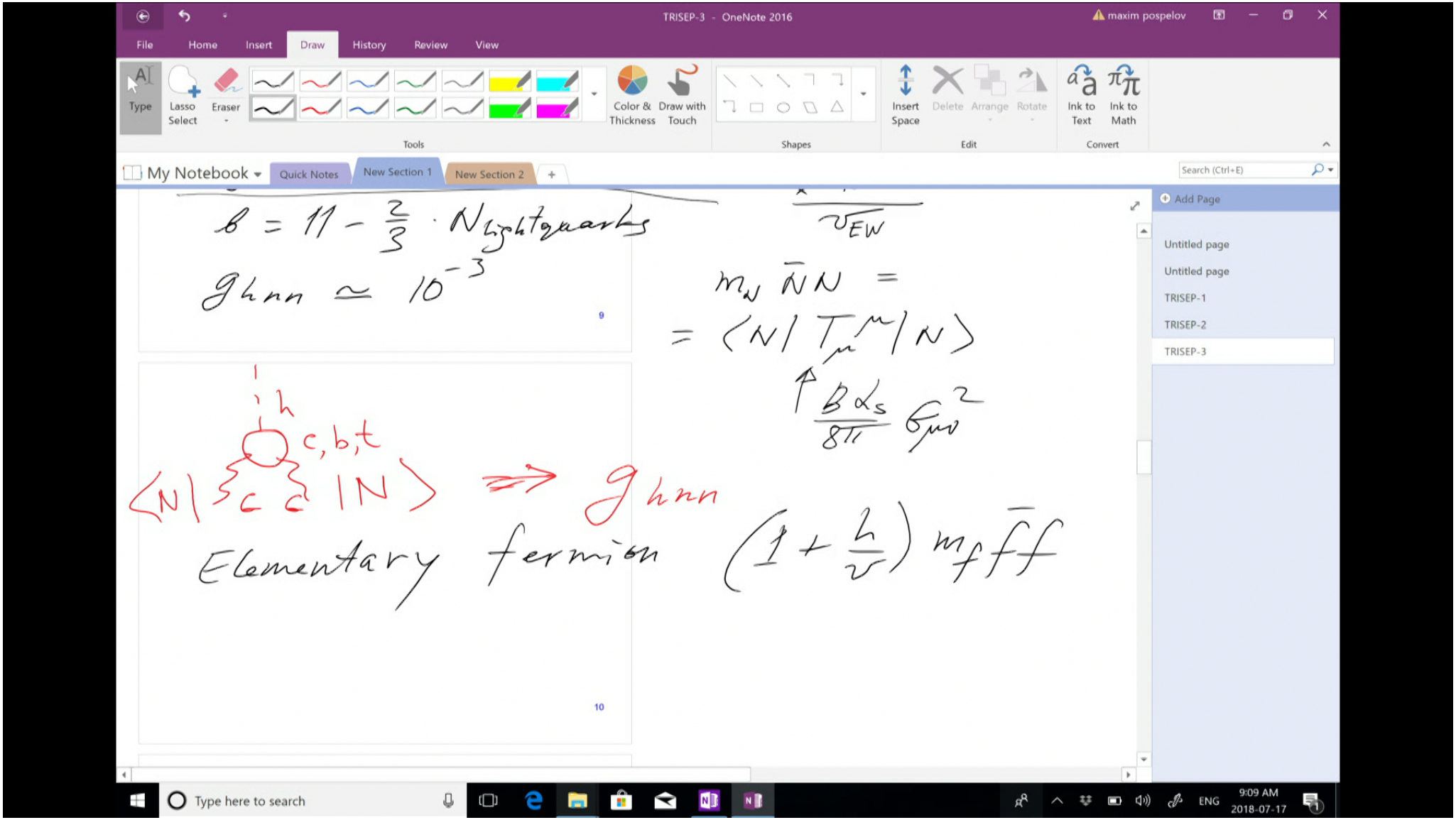

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gNNπ ← has to be small (light particles)
Nucleon contains light particles
(light quarks, gluons)
In the limit of Mu,d,s → 0 (chiral limit)
70 MeV
gNNπ ≃ N heavy quarks / v · 2/3 · mN/B ≃ 3 N heavy quarks × 70 MeV / vEW
b = 11 − 2/3 · N light quarks
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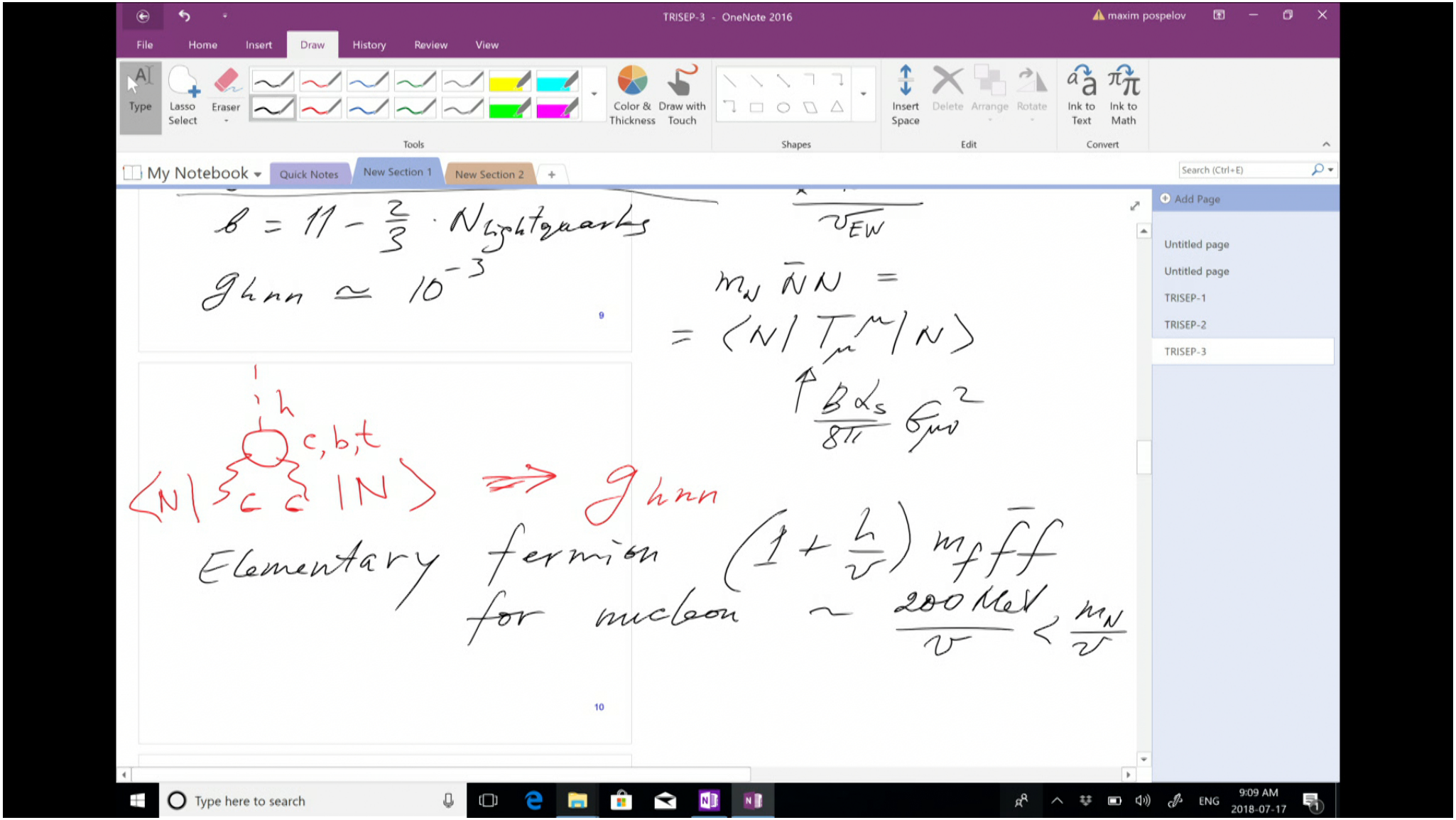

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g_{hnn} ← has to be small (?)
Nucleon contains light particles
(light quarks, gluons)
In the limit of $m_{u,d,s} \to 0$ (chiral limit)
$g_{hnn} \simeq \frac{N_{heavy\ quarks}}{v} \frac{2}{3} \frac{m_N}{B} \simeq \frac{3 N_{heavy\ quarks} \times 70\ MeV}{v_{EW}}$
$b = 11 - \frac{2}{3} \cdot N_{light\ quarks}$
$g_{hnn} \simeq 10^{-3}$
$m_N \bar{N} N =$
$= \langle N | T^{\mu}_{\mu} | N \rangle$
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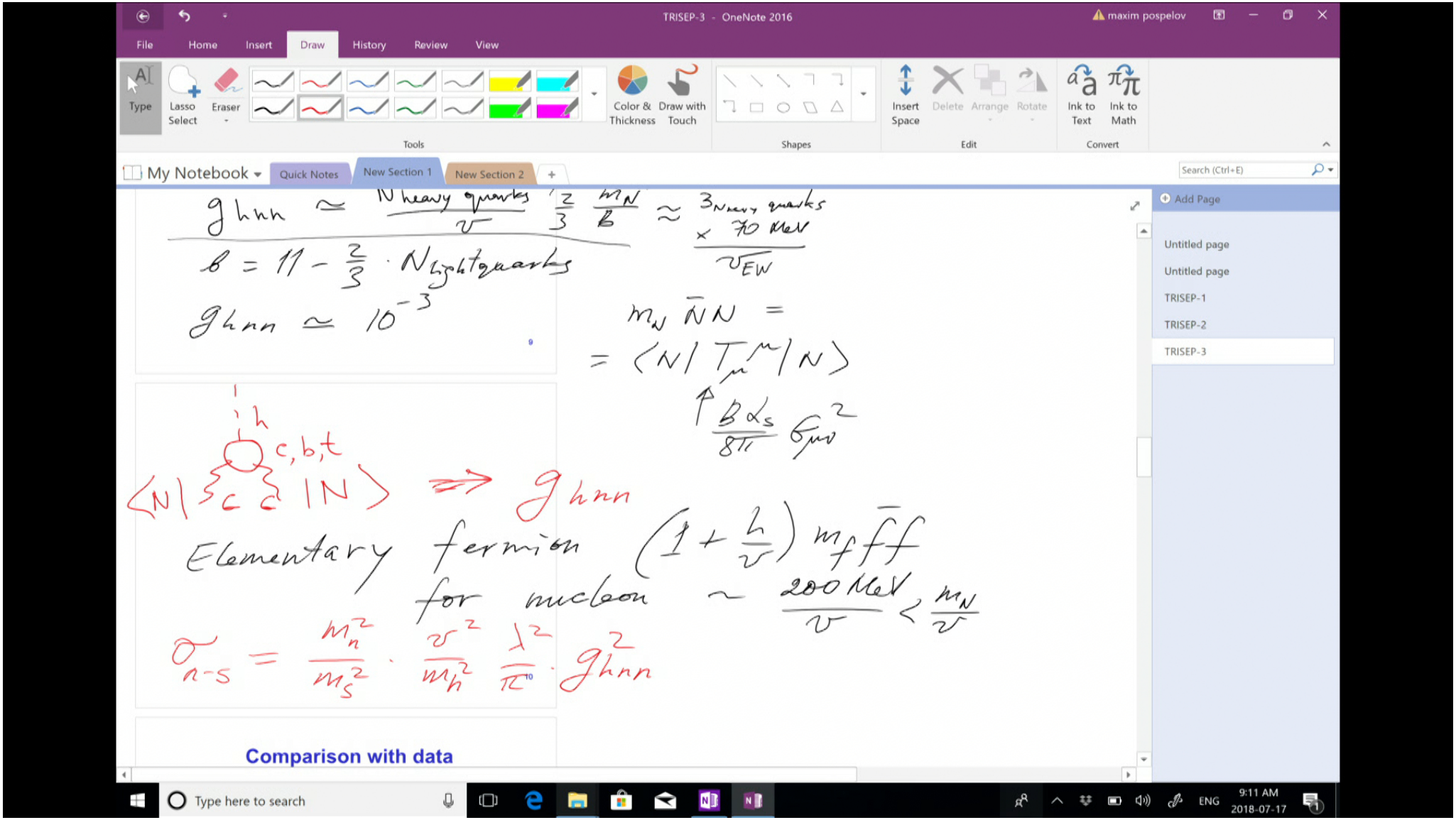

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$\beta = 11 - \frac{2}{3} \cdot N_{light\,quarks}$
$g_{hnn} \simeq 10^{-3}$
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$m_N \bar{N} N =$
$= \langle N | T^{\mu}_{\mu} | N \rangle$
$\frac{\beta \alpha_s}{8\pi} G_{\mu\nu}^2$
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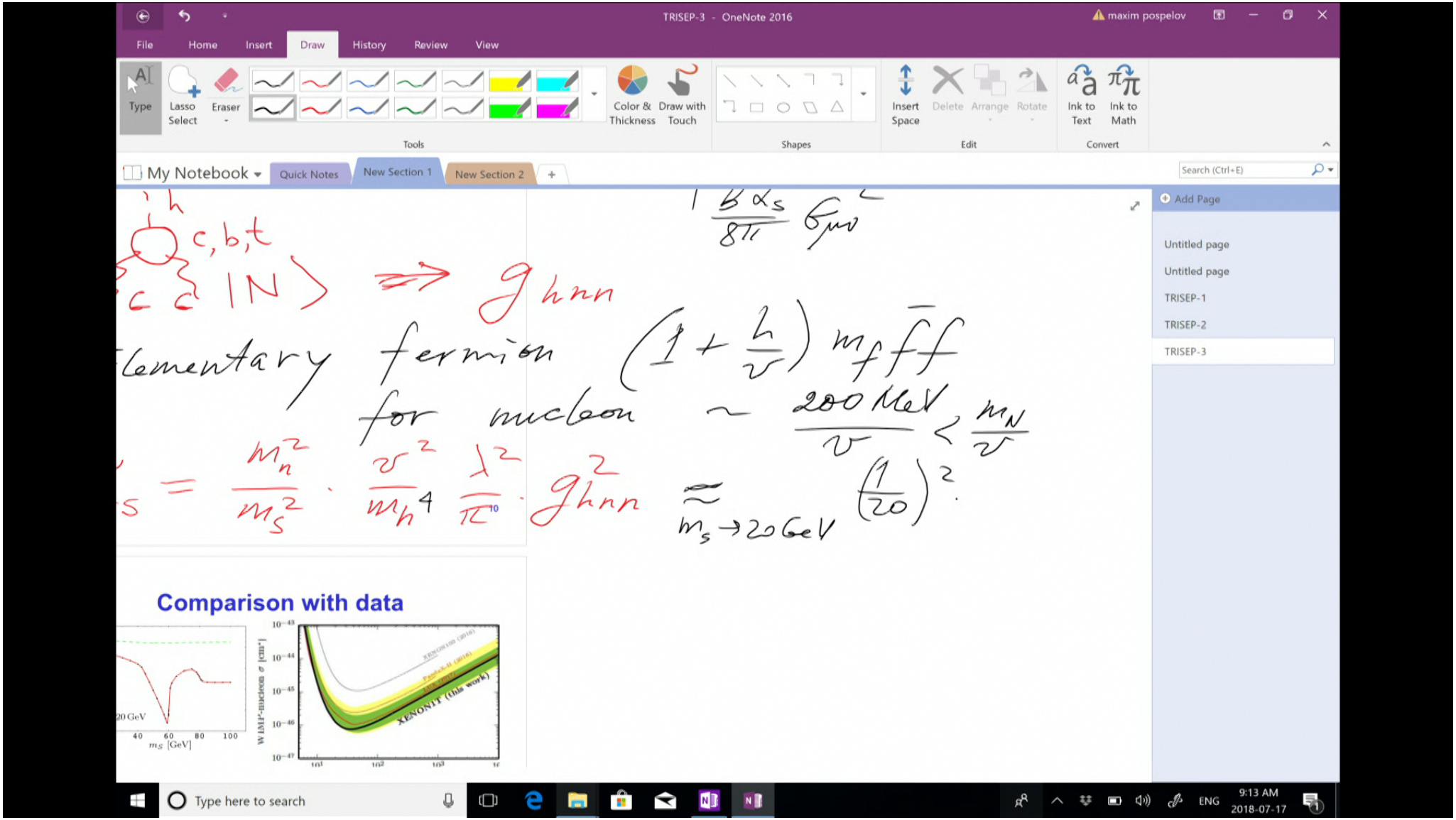

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In the limit of $M_{u,d,s} \to 0$ (70 MeV) (chiral limit)
$g_{hnn} \simeq \frac{N_{heavy\ quarks}}{v} \frac{2}{3} \frac{m_N}{b} \simeq \frac{3 N_{heavy\ quarks} \times 70\ MeV}{v_{EW}}$
$b = 11 - \frac{2}{3} \cdot N_{light\ quarks}$
$g_{hnn} \simeq 10^{-3}$
$m_N \bar{N} N =$
$= \langle N | T^{\mu}_{\mu} | N \rangle$
$\frac{b \alpha_s}{8\pi} G_{\mu\nu}^2$
h
c,b,t
$\langle N | s\bar{s} | N \rangle =$
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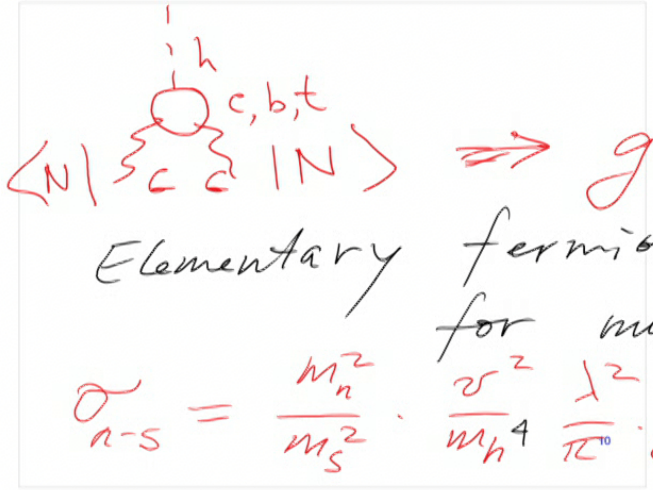

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$b = 11 - \frac{2}{3} \cdot N_{\text{lightquarks}}$
$g_{hnn} \simeq 10^{-3}$
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v_{EW}
$m_N \bar{N} N =$
$= \langle N | T^{\mu}_{\mu} | N \rangle$
$\frac{b \alpha_s}{8\pi} G_{\mu\nu}^2$
h
c, b, t
$\langle N | s\bar{s} | N \rangle \Rightarrow g_{hnn}$
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$b = 11 - \frac{2}{3} \cdot N_{lightquarks}$
$g_{hnn} \simeq 10^{-3}$
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v_{EW}
$m_N \bar{N} N =$
$= \langle N | T^{\mu}_{\mu} | N \rangle$
$\frac{\beta}{8\pi} \alpha_s G_{\mu\nu}^2$
h
c, b, t
$\langle N | s\bar{s} | N \rangle \Rightarrow g_{hnn}$
Elementary fermion
$\left(1 + \frac{h}{v}\right) m_f \bar{f} f$
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$b = 11 - \frac{2}{3} \cdot N_{lightquarks}$
$g_{hnn} \simeq 10^{-3}$
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v_{EW}
$m_N \bar{N} N =$
$= \langle N | T^{\mu}_{\mu} | N \rangle$
$\frac{b \alpha_s}{8\pi} G_{\mu\nu}^2$
h
c,b,t
$\langle N | s\bar{s} | N \rangle \Rightarrow g_{hnn}$
Elementary fermion
for nucleon
$\left(1 + \frac{h}{v}\right) m_f \bar{f} f$
$\sim \frac{200\,MeV}{v} < \frac{m_N}{v}$
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c,b,t
g_{hnn}
fermion
for nucleon
$(1+\frac{h}{v})\, m_f \bar{f} f$
$\sim \frac{200\,MeV}{v} < \frac{m_N}{v}$
$\simeq$
$m_s \to 20\,GeV$
$(\frac{1}{20})^2$
Comparison with data
20 GeV
m_S [GeV]
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$$\frac{\beta \alpha_s}{8\pi} G_{\mu\nu}^2$$

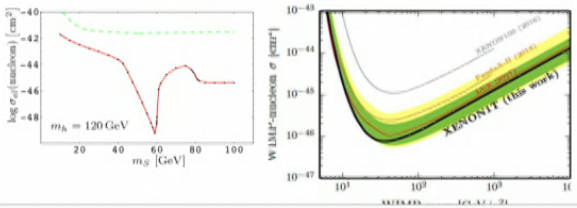
$$\left(1 + \frac{h}{v}\right) m_f \bar{f} f$$

$$\sim \frac{200\ \text{MeV}}{v} < \frac{m_N}{v}$$

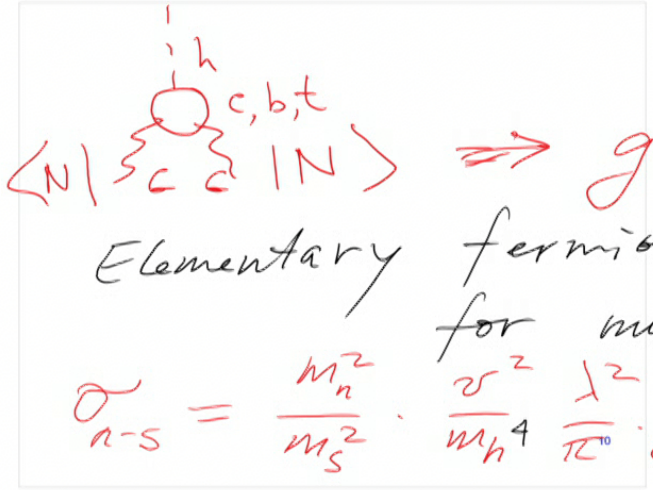
$$\sigma_{n-S} = \frac{m_n^2}{m_S^2} \cdot \frac{v^2}{m_h^4} \frac{\lambda^2}{\pi^{10}} \cdot g_{hnn}^2 \simeq$$

$$m_S \to 20\ \text{GeV} \quad \left(\frac{1}{20}\right)^2 \cdot \frac{246^2}{125^4} \cdot \text{GeV}^{-2} \times \frac{\lambda^2}{\pi} \times 10^{-6}$$

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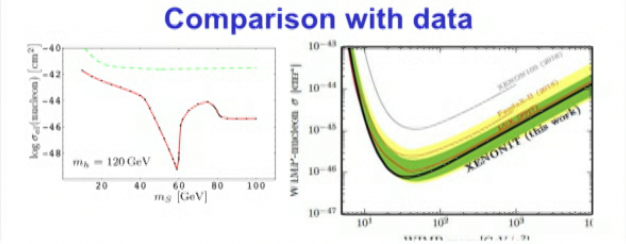
$$\sigma_{n-S} = \frac{m_n^2}{m_S^2} \cdot \frac{v^2}{m_h^4} \cdot \frac{\lambda^2}{\pi^{10}} \cdot g_{hnn}^2$$

$$\left(1 + \frac{h}{v}\right) m_f \bar{f} f$$

$$\sim \frac{200\,\text{MeV}}{v} < \frac{m_N}{v}$$

$$\simeq_{m_S \to 20\,\text{GeV}} \left(\frac{1}{20}\right)^2 \cdot \frac{246^2}{125^4} \cdot \text{GeV}^{-2} \times \lambda^2 \times 10^{-6}$$

$$= \frac{(0.2\,\text{GeV} \times 10^{-13}\,\text{cm})^2}{\text{GeV}^2} \pi \left(\frac{1}{20}\right)^2 \times \frac{2.46^2}{1.25^4} \cdot 10^{-4} \times \frac{0.1}{\pi} \times 10^{-6}$$



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for nucleon $\sim \frac{200\,\text{MeV}}{v} < \frac{m_N}{v}$

$\frac{v^2}{m_h^4} \frac{\lambda^2}{\pi^{10}} \cdot g_{hnn}^2 \simeq$

$m_s \to 20\,\text{GeV}$ $\left(\frac{1}{20}\right)^2 \cdot \frac{246^2}{125^4} \cdot \text{GeV}^{-2}$

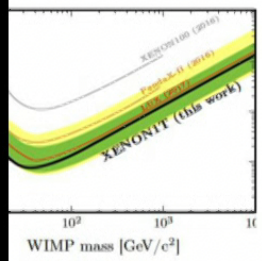
$\times \frac{\lambda^2}{\pi} \times 10^{-6}$

$= \frac{(0.2\,\text{GeV} \times 10^{-13}\,\text{cm})^2}{\text{GeV}^2} \left(\frac{1}{20}\right)^2 \times \frac{2.46^2}{1.25^4} \cdot 10^{-4}$

$\times \frac{0.1}{\pi} \times 10^{-6} =$

$= 10^{-26}\,\text{cm}^2 \frac{(0.2)^2}{20^2} \cdot 10^{-4} \cdot 10^{-7} \frac{2.46^2}{\pi\, 1.25^4}$

h data



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$$\frac{v}{m_h^4}\,\frac{\lambda^2}{\pi^{10}}\cdot g_{hnn}^2 \simeq \left(\frac{1}{20}\right)^2\cdot\frac{246^2}{125^4}\cdot \text{GeV}^{-2}$$

$m_s \to 20\,\text{GeV}$

$$\times\frac{\lambda^2}{\pi}\times 10^{-6} = \frac{(0.2\,\text{GeV}\times 10^{-13}\,\text{cm})^2}{\text{GeV}^2}\left(\frac{1}{20}\right)^2\times\frac{2.46^2}{1.25^4}\cdot 10^{-4}$$

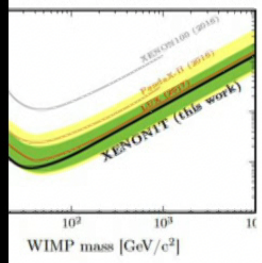
$$\times\frac{0.1}{\pi}\times 10^{-6} =$$

$$= 10^{-26}\,\text{cm}^2\,\frac{(0.2)^2}{20^2}\cdot 10^{-4}\cdot 10^{-7}\,\frac{2.46^2}{\pi\,1.25^4}$$

$$= 10^{-26}\,\text{cm}^2\cdot 10^{-4}\cdot 10^{-11}\,O(1)$$

$$= 10^{-41}/\text{cm}^2$$

h data



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$$\sigma_{n-S} = \frac{m_n}{m_S^2} \cdot \frac{v^2}{m_h^4} \cdot \frac{\lambda^2}{\pi^{10}} \cdot g_{hnn}^2 \simeq$$

$m_S \to 20\,\text{GeV}$

$$\left(\frac{1}{20}\right)^2 \cdot \frac{246}{125^4} \times \lambda^2 \times 10^{-6}$$

$$= \frac{(0.2\,\text{GeV} \times 10^{-13}\,\text{cm})^2}{\text{GeV}^2} \pi \left(\frac{1}{20}\right)^2 \times \frac{2.46}{1.25}$$

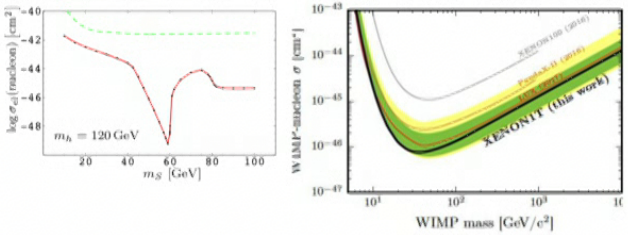
$$\times \frac{0.1}{\pi} \times 10^{-6} =$$

$$= 10^{-26}\,\text{cm}^2 \frac{(0.2)^2}{20^2} \cdot 10^{-4} \cdot 10$$

$$= 10^{-26}\,\text{cm}^2 \cdot 10^{-4} \cdot 10^{-11} \quad O(1$$

$$= 10^{-41}/\text{cm}^2$$

Comparison with data



11

Simplest models of Higgs mediation

Silveira, Zee (1985); McDonald (1993); Burgess, MP, ter Veldhuis(200(

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Updates on the minimal Higgs-mediated model:

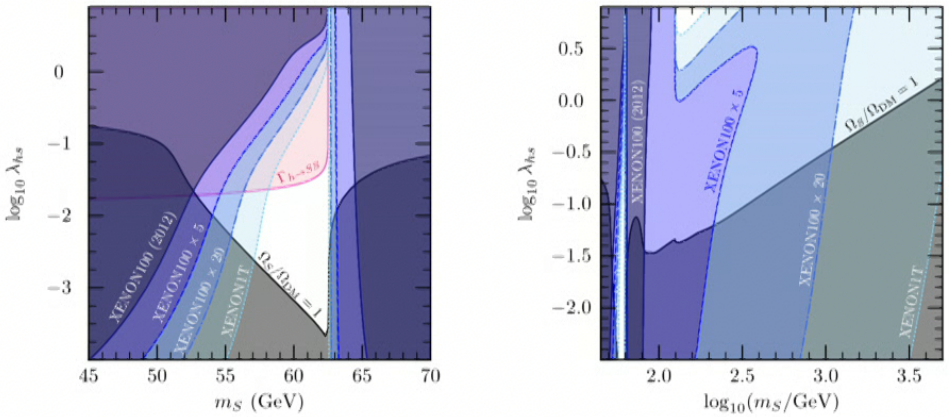
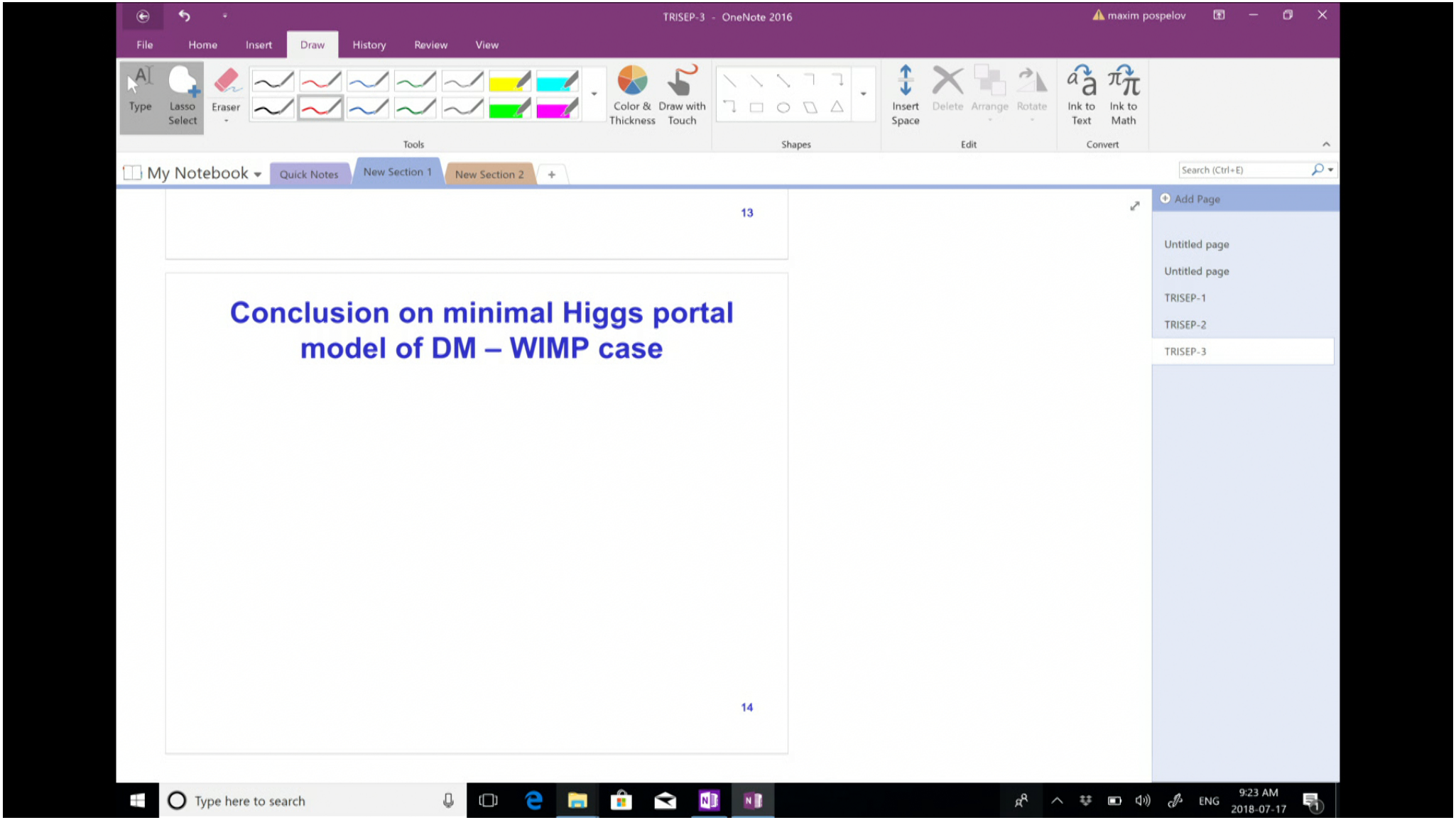
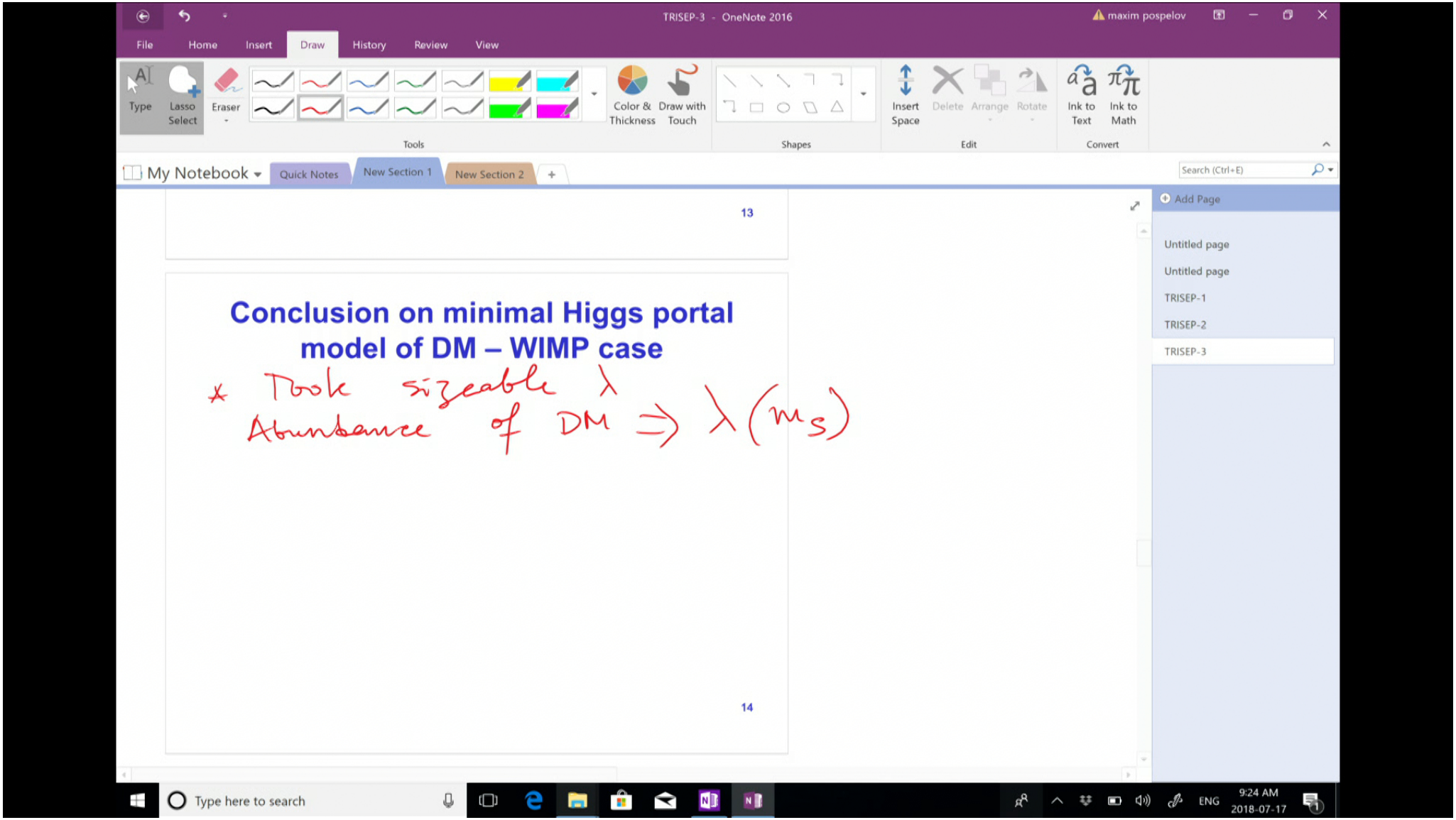
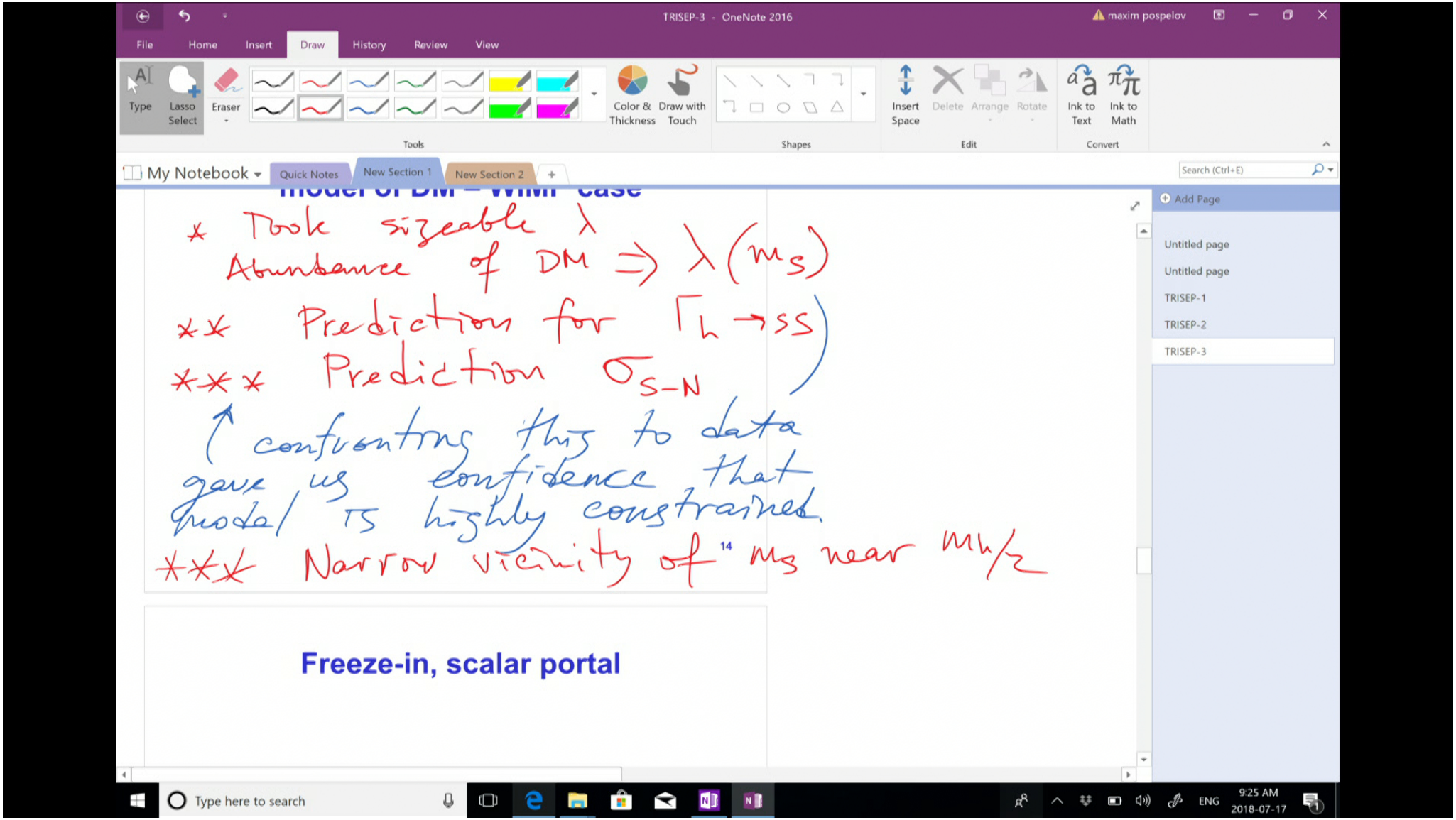
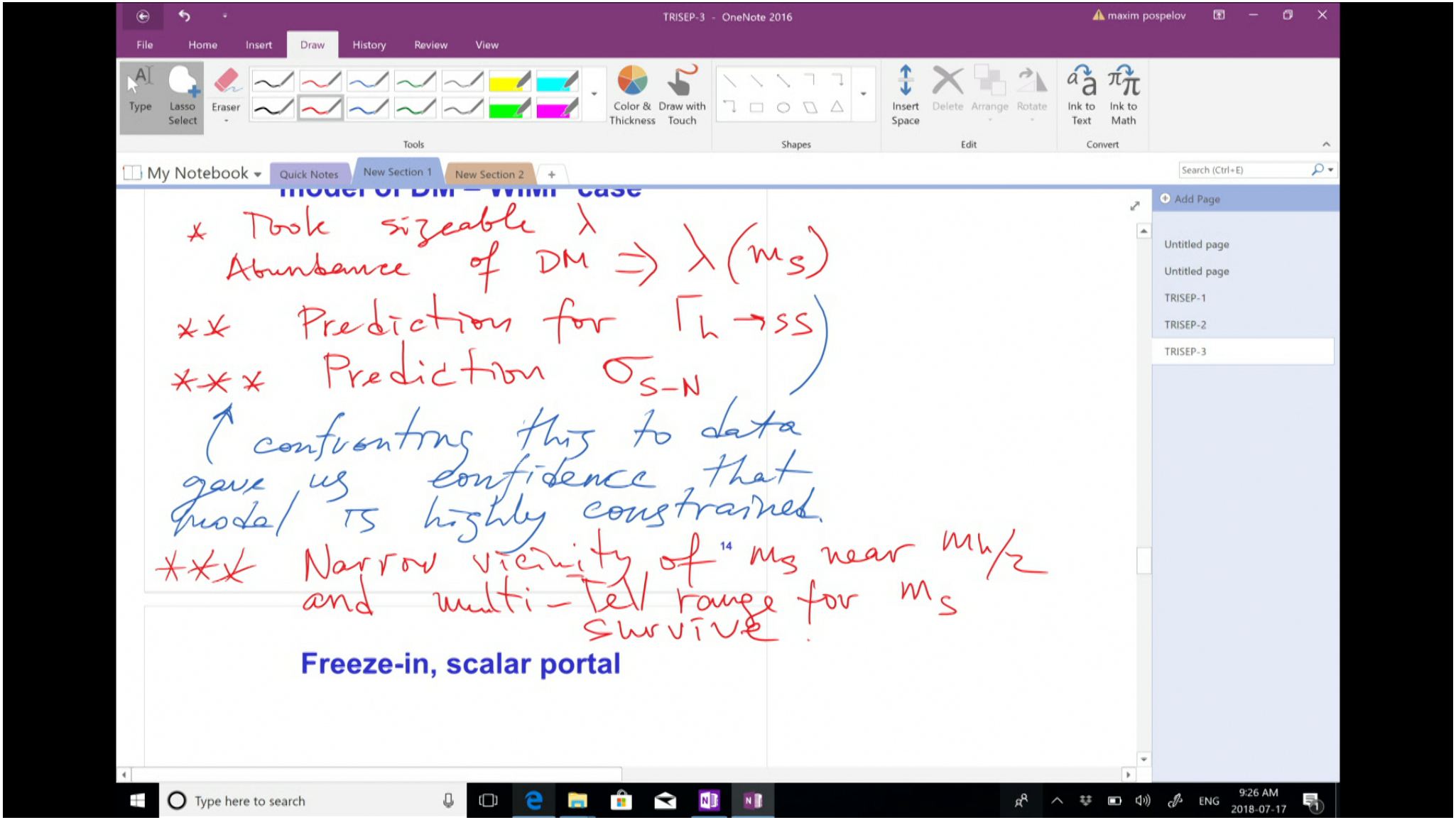


Figure from Cline, Scott, Kainulainen, Weniger, 2013.


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Conclusion on minimal Higgs portal model of DM – WIMP case
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Conclusion on minimal Higgs portal model of DM – WIMP case
* Took sizeable λ
Abundance of DM ⇒ λ(m_S)
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* Took sizeable λ
Abundance of DM ⇒ λ(m_S)
** Prediction for Γ_h → SS)
*** Prediction σ_{S-N}
(confronting this to data gave us confidence that model is highly constrained.
*** Narrow vicinity of m_S near m_h/2
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Freeze-in, scalar portal
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* Took sizeable λ
Abundance of DM ⇒ λ(m_S)
** Prediction for Γ_h→SS)
*** Prediction σ_S-N
(confronting this to data gave us confidence that model is highly constrained.
*** Narrow vicinity of 14 m_S near m_h/2 and multi-TeV range for m_S survive!
Freeze-in, scalar portal
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