Title: PHYS 781 - Lecture 23

Date: Nov 25, 2014 02:00 PM

URL: http://pirsa.org/14110052

Abstract:

$$a + X \longrightarrow Z^* \longrightarrow b + Y$$

Resonant Cross-section

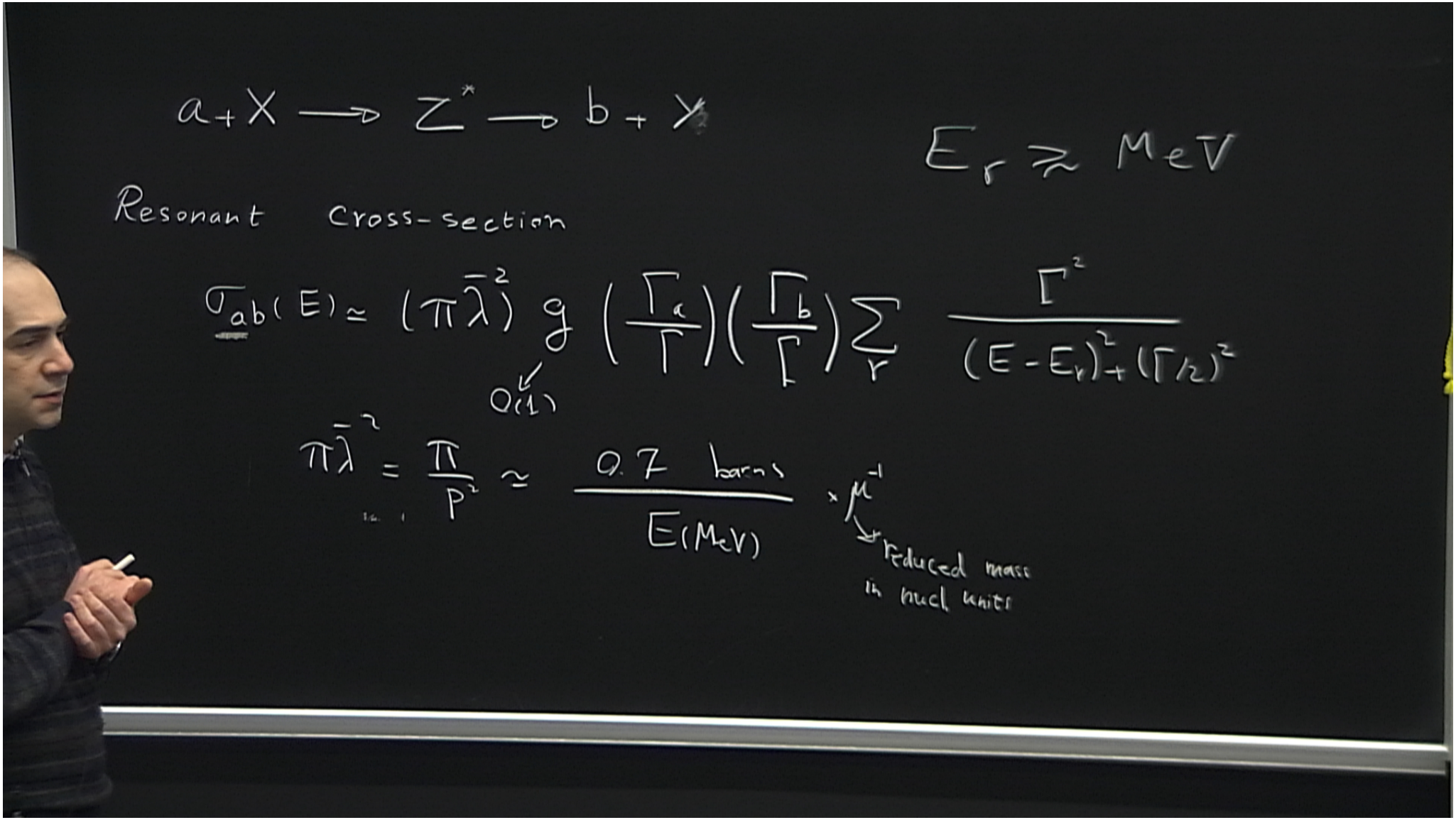
$$\sigma_{ab}(E) \simeq (\pi \bar{\lambda}^2)\, g \left(\frac{\Gamma_a}{\Gamma}\right)\left(\frac{\Gamma_b}{\Gamma}\right) \sum_r \frac{\Gamma^2}{(E - E_r)^2 + (\Gamma/2)^2}$$

$a + X \longrightarrow C^* \longrightarrow b + Y$

$E_r \gtrsim MeV$

Resonant Cross-section

$$\sigma_{ab}(E) \simeq (\pi \bar{\lambda}^2)\, g \left(\frac{\Gamma_a}{\Gamma}\right)\left(\frac{\Gamma_b}{\Gamma}\right) \sum_r \frac{\Gamma^2}{(E - E_r)^2 + (\Gamma/2)^2}$$


$a + X \longrightarrow C^* \longrightarrow b + Y$
$E_r \gtrsim MeV$
Resonant cross-section
$\sigma_{ab}(E) \simeq (\pi\bar{\lambda}^2)\, g \left(\frac{\Gamma_a}{\Gamma}\right)\left(\frac{\Gamma_b}{\Gamma}\right) \sum_r \frac{\Gamma^2}{(E-E_r)^2 + (\Gamma/2)^2}$
$O(1)$
$\pi\bar{\lambda}^2 = \frac{\pi}{p^2} \simeq \frac{0.7 \text{ barns}}{E(MeV)} \times \mu^{-1}$
reduced mass in nucl units

$a + X \longrightarrow Z^* \longrightarrow b + Y$

$E_r \gtrsim MeV$

Resonant Cross-section

$$\sigma_{ab}(E) \simeq (\pi\bar{\lambda}^2)\, g\, \left(\frac{\Gamma_a}{\Gamma}\right)\left(\frac{\Gamma_b}{\Gamma}\right) \sum_r \frac{\Gamma^2}{(E - E_r)^2 + (\Gamma/2)^2}$$

g: $O(1)$

$$\pi\bar{\lambda}^2 = \frac{\pi}{p^2} \simeq \frac{0.7 \text{ barns}}{E(MeV)} \times \mu^{-1}$$

μ: reduced mass in nucl units

$a + X \longrightarrow C^* \longrightarrow b + Y$

$E_r \gtrsim MeV$

Resonant Cross-section

$$\sigma_{ab}(E) \simeq (\pi \bar{\lambda}^2)\, g \left(\frac{\Gamma_a}{\Gamma}\right)\left(\frac{\Gamma_b}{\Gamma}\right) \sum_r \frac{\Gamma^2}{(E - E_r)^2 + (\Gamma/2)^2}$$

$g \sim O(1)$

$$\Gamma = \sum_a \Gamma_a$$

$$\pi \bar{\lambda}^2 = \frac{\pi}{p^2} \simeq \frac{0.7 \text{ barns}}{E(MeV)} \times \mu^{-1}$$

μ: reduced mass in nucl. units

$a + X \longrightarrow C^* \longrightarrow b + Y$

$E_r \gtrsim MeV \sim 10^{10} K$

Resonant Cross-section

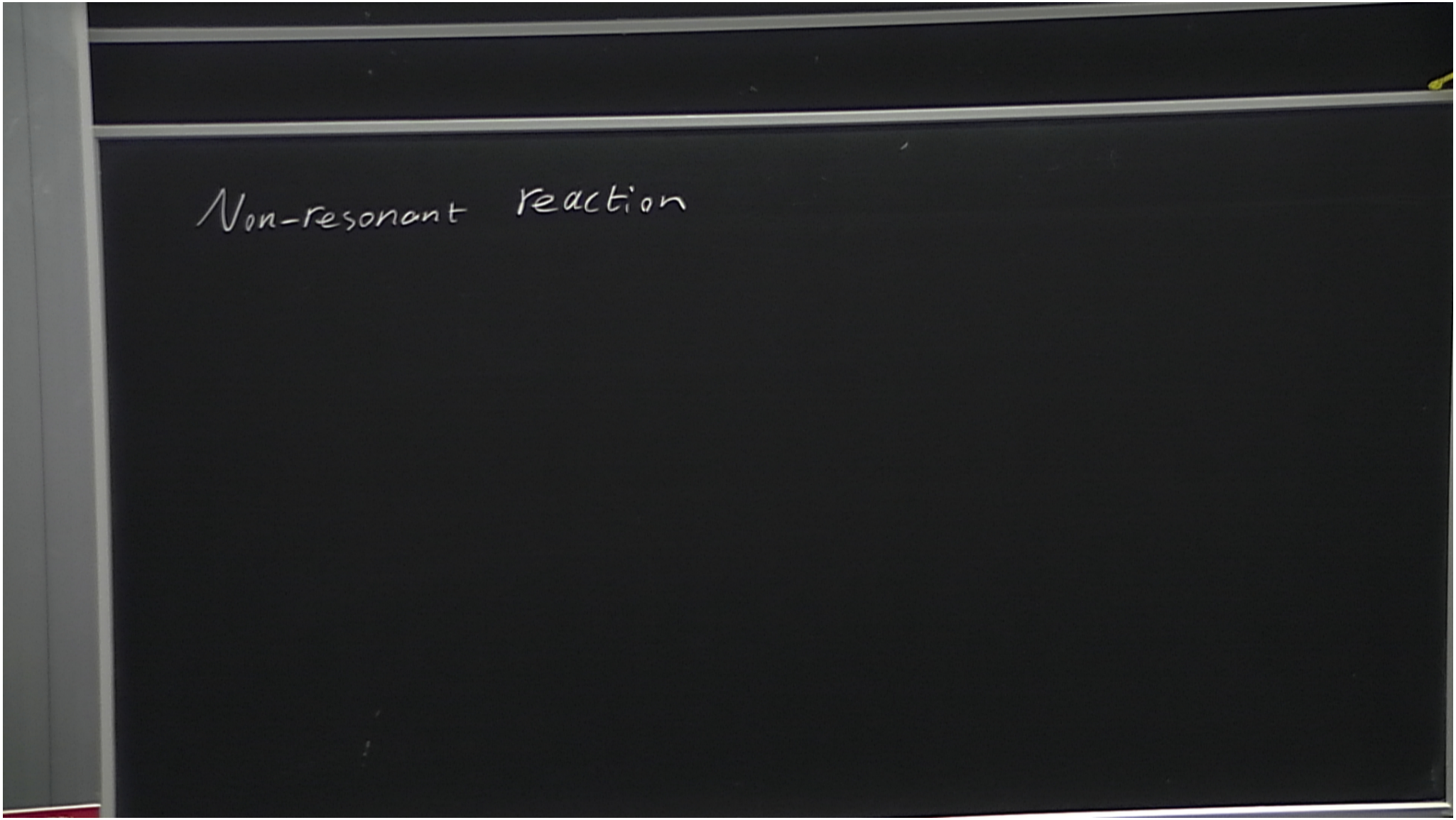
$$\sigma_{ab}(E) \simeq (\pi \bar{\lambda}^2)\, g \left(\frac{\Gamma_a}{\Gamma}\right)\left(\frac{\Gamma_b}{\Gamma}\right) \sum_r \frac{\Gamma^2}{(E - E_r)^2 + (\Gamma/2)^2}$$

$g \sim O(1)$

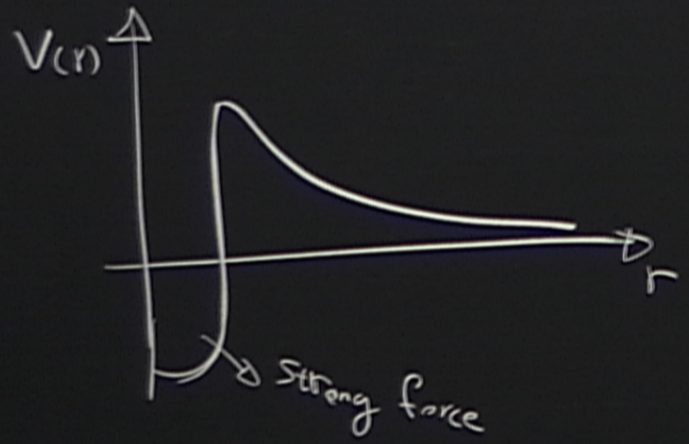
$$\Gamma = \sum_a \Gamma_a$$

$$\pi \bar{\lambda}^2 = \frac{\pi}{p^2} \simeq \frac{0.7 \text{ barns}}{E(MeV)} \times \mu^{-1}$$

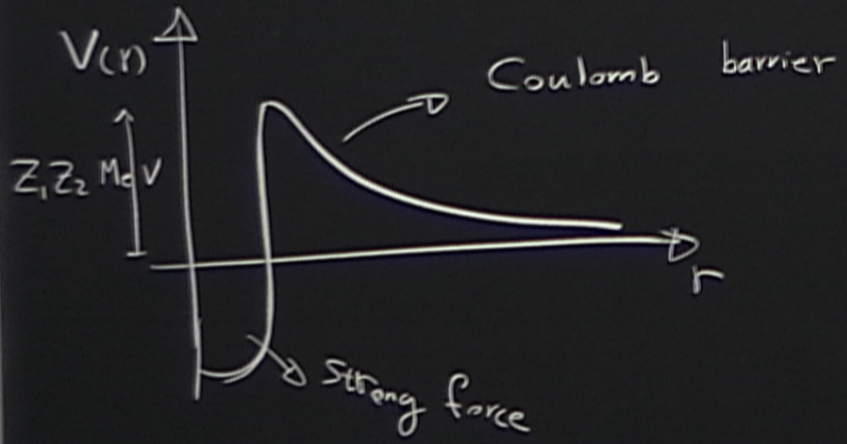
μ: reduced mass in nucl units


Non-resonant reaction

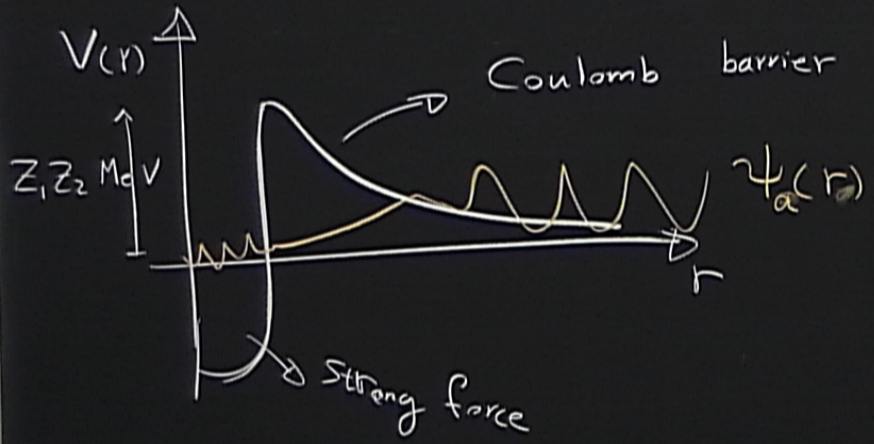
Non-resonant reaction

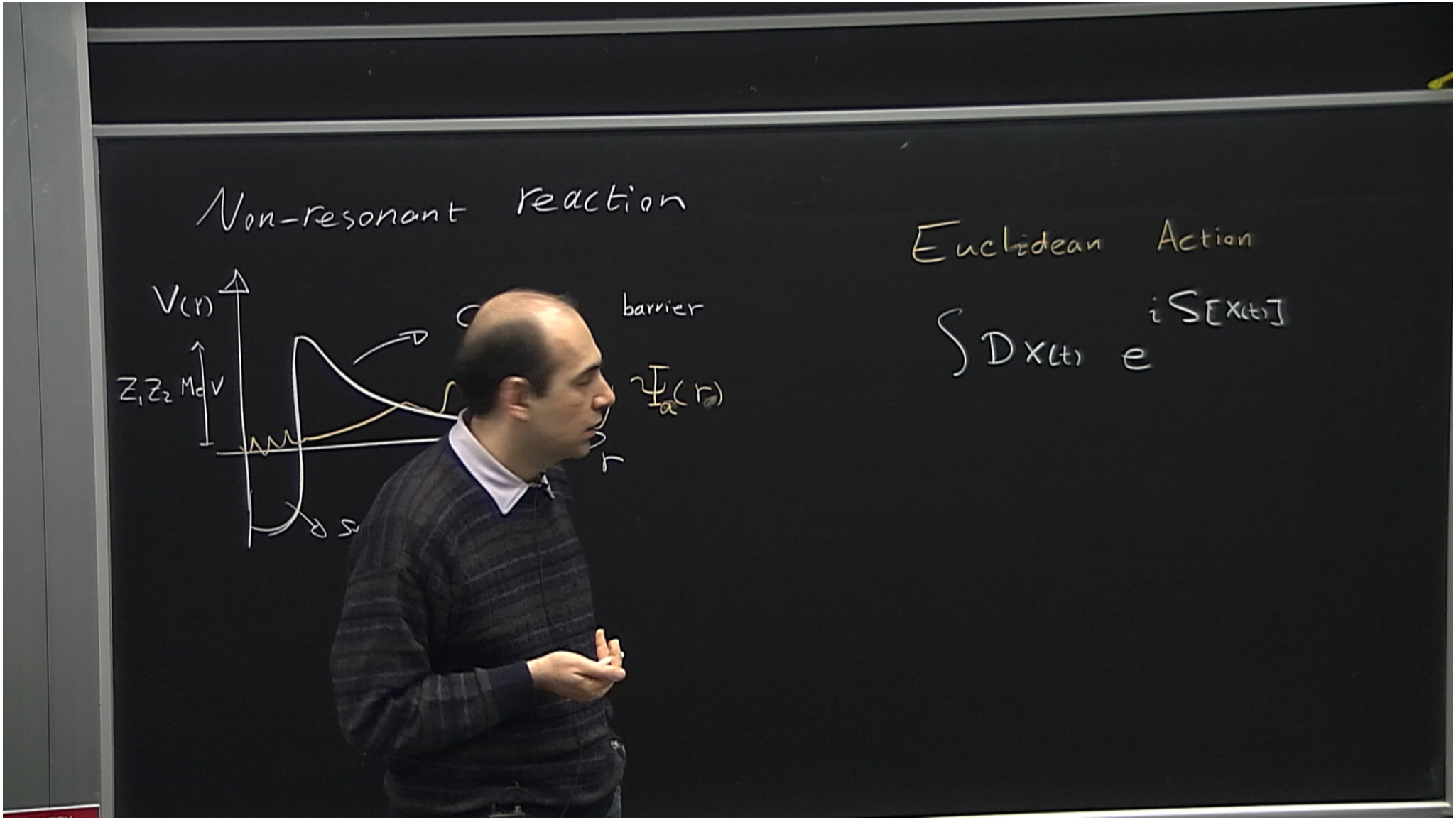


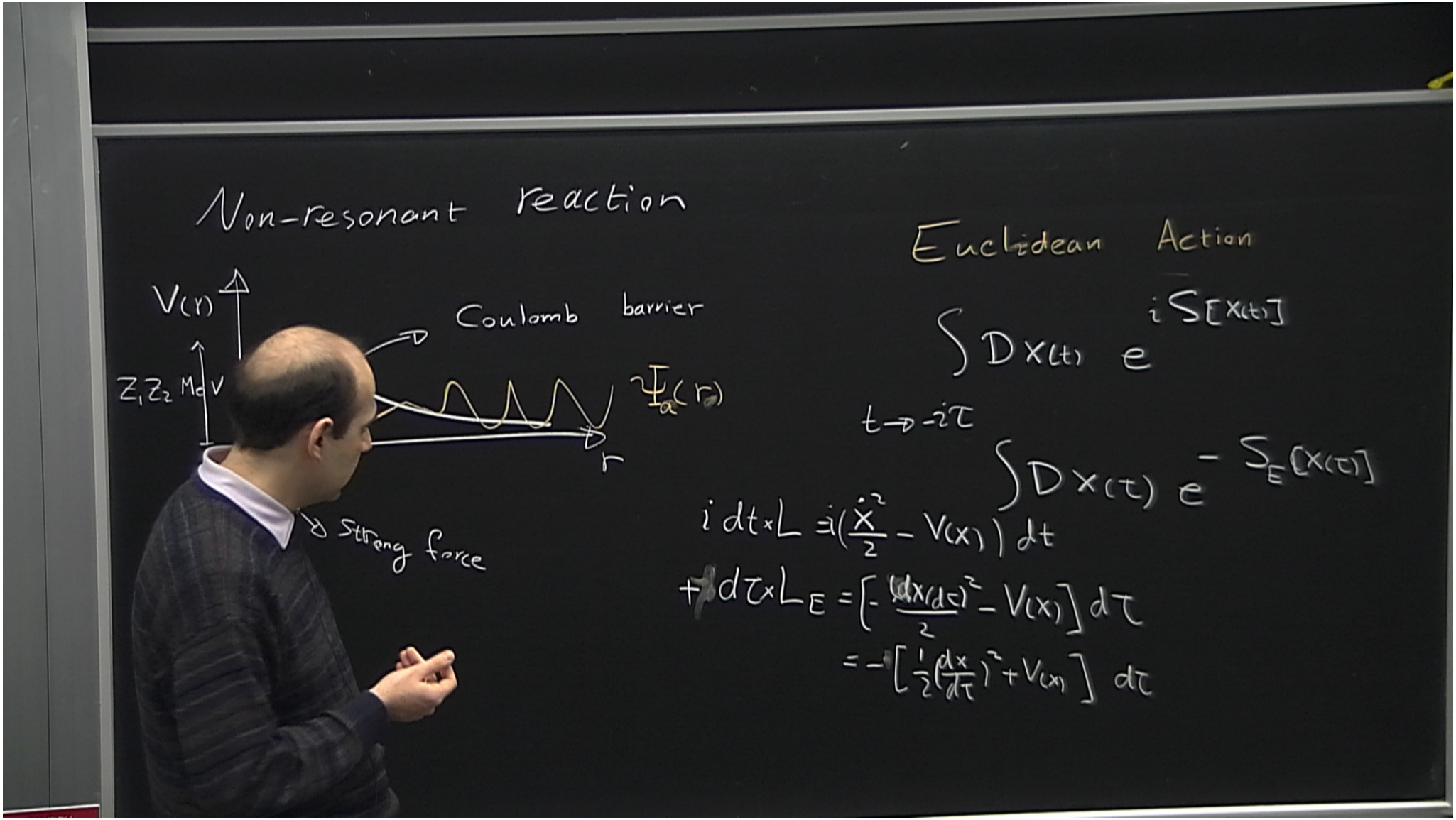
Non-resonant reaction



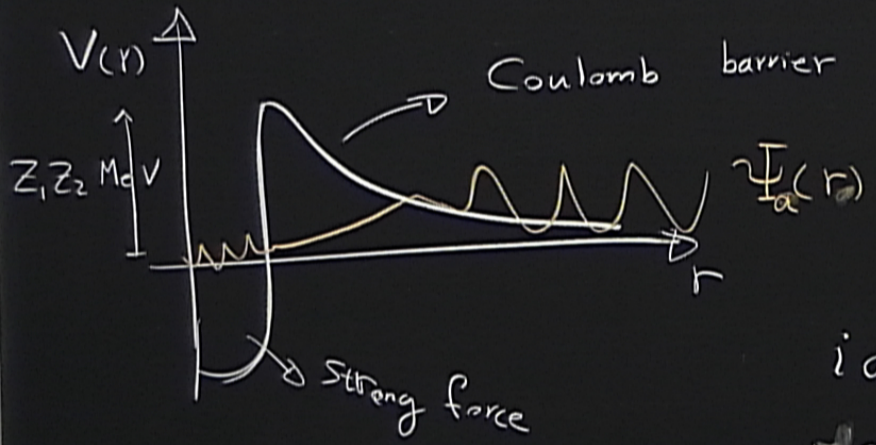
Non-resonant reaction




Non-resonant reaction
V(r)
barrier
$Z_1 Z_2 e^2/r$
$\psi_a(r_a)$
r
s
Euclidean Action
$\int Dx(t)\, e^{iS[x(t)]}$


Non-resonant reaction
V(r)
Coulomb barrier
$Z_1 Z_2 e^2$
$\Psi_a(r)$
r
Strong force
Euclidean Action
$\int Dx(t)\, e^{iS[x(t)]}$
$t \to -i\tau$
$\int Dx(\tau)\, e^{-S_E[x(\tau)]}$
$i\,dt \times L = i\left(\frac{\dot{x}^2}{2} - V(x)\right) dt$
$+ d\tau \times L_E = \left[-\frac{\left(\frac{dx}{d\tau}\right)^2}{2} - V(x)\right] d\tau$
$= -\left[\frac{1}{2}\left(\frac{dx}{d\tau}\right)^2 + V(x)\right] d\tau$

Non-resonant reaction



Euclidean Action

$$\int Dx(t)\, e^{iS[x(t)]}$$

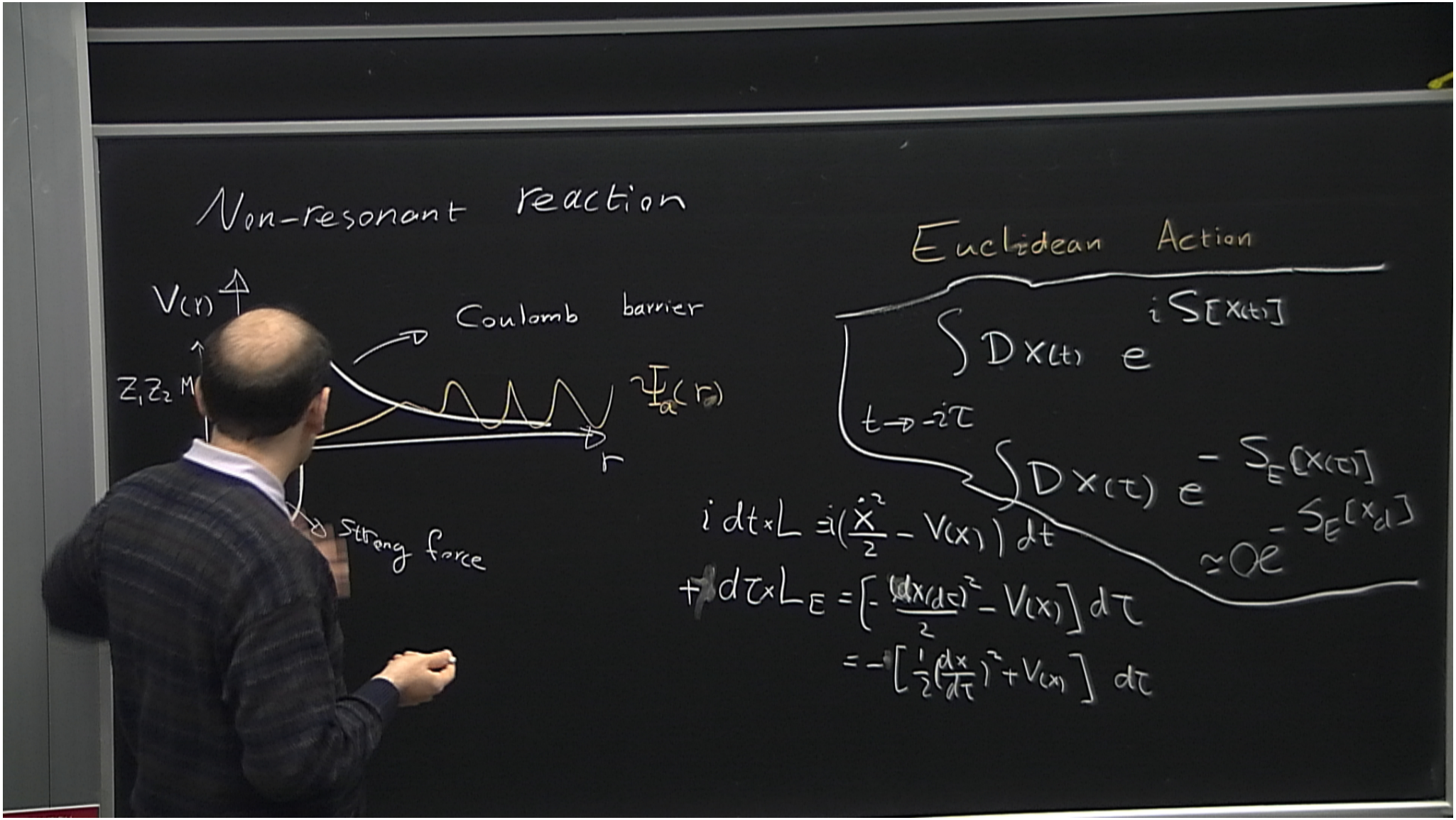
$t \to -i\tau$

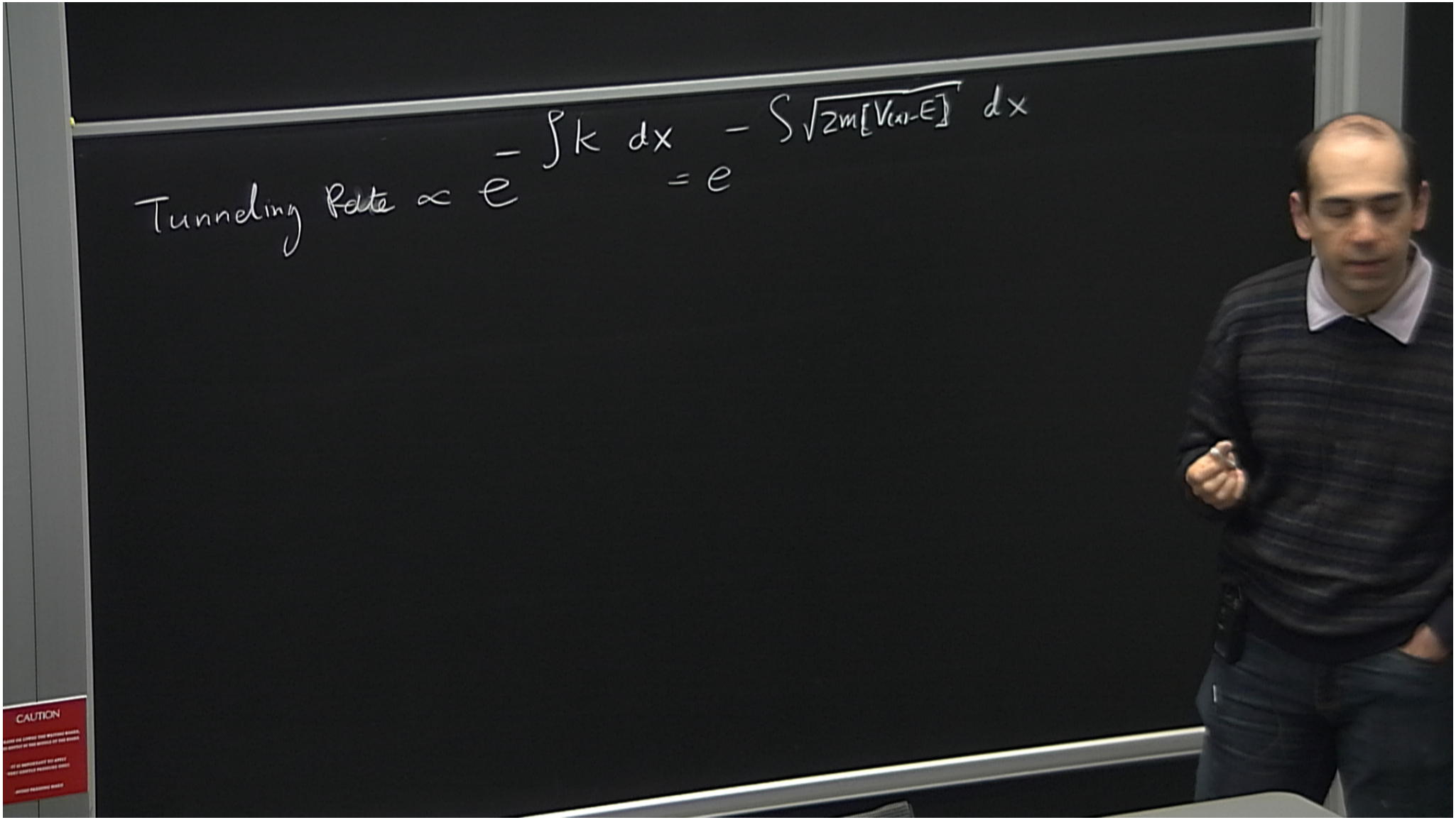
$$\int Dx(\tau)\, e^{-S_E[x(\tau)]} \simeq e^{-S_E[x_{cl}]}$$

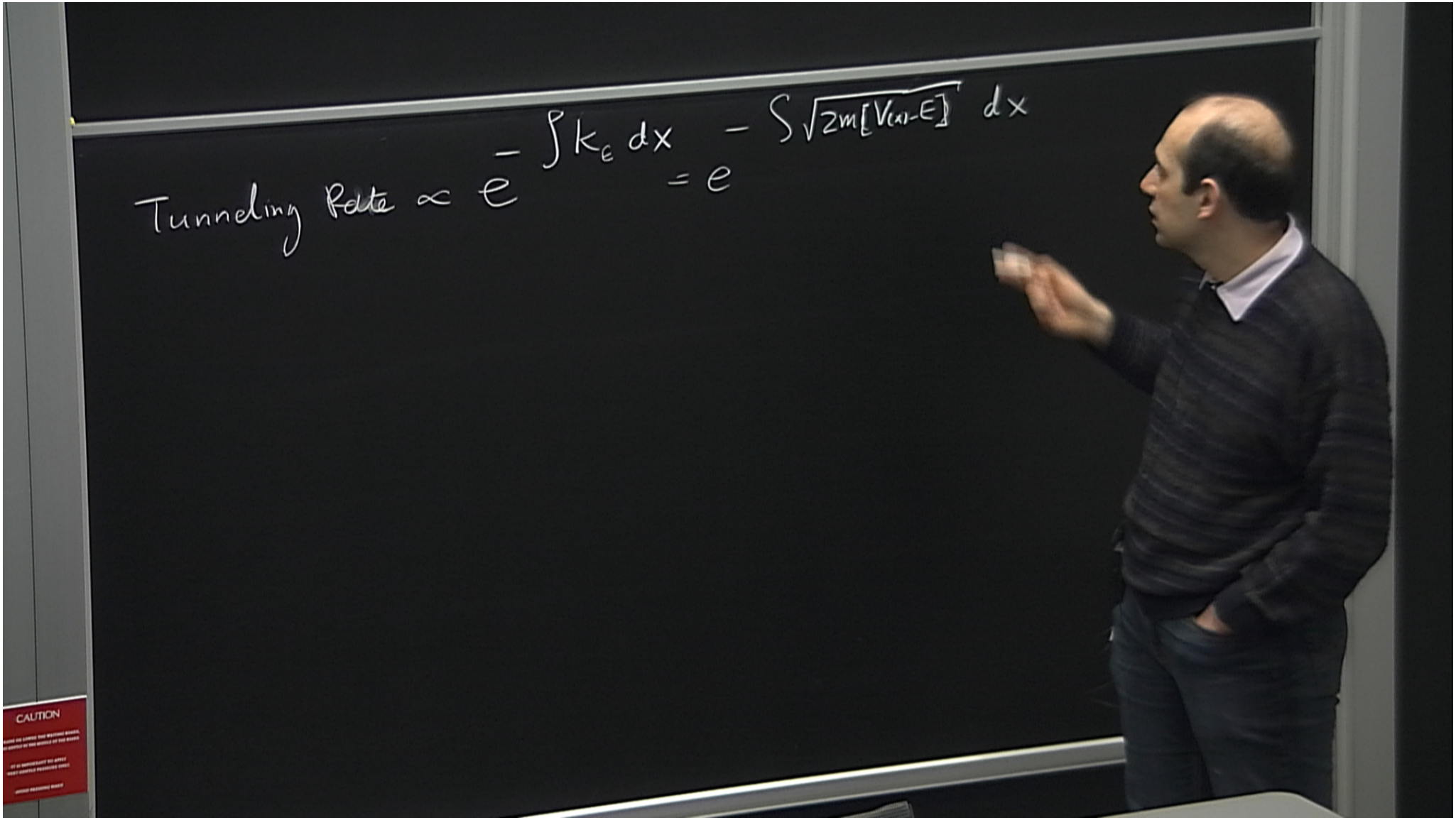
$$i\,dt \times L = i\left(\frac{\dot{x}^2}{2} - V(x)\right) dt$$

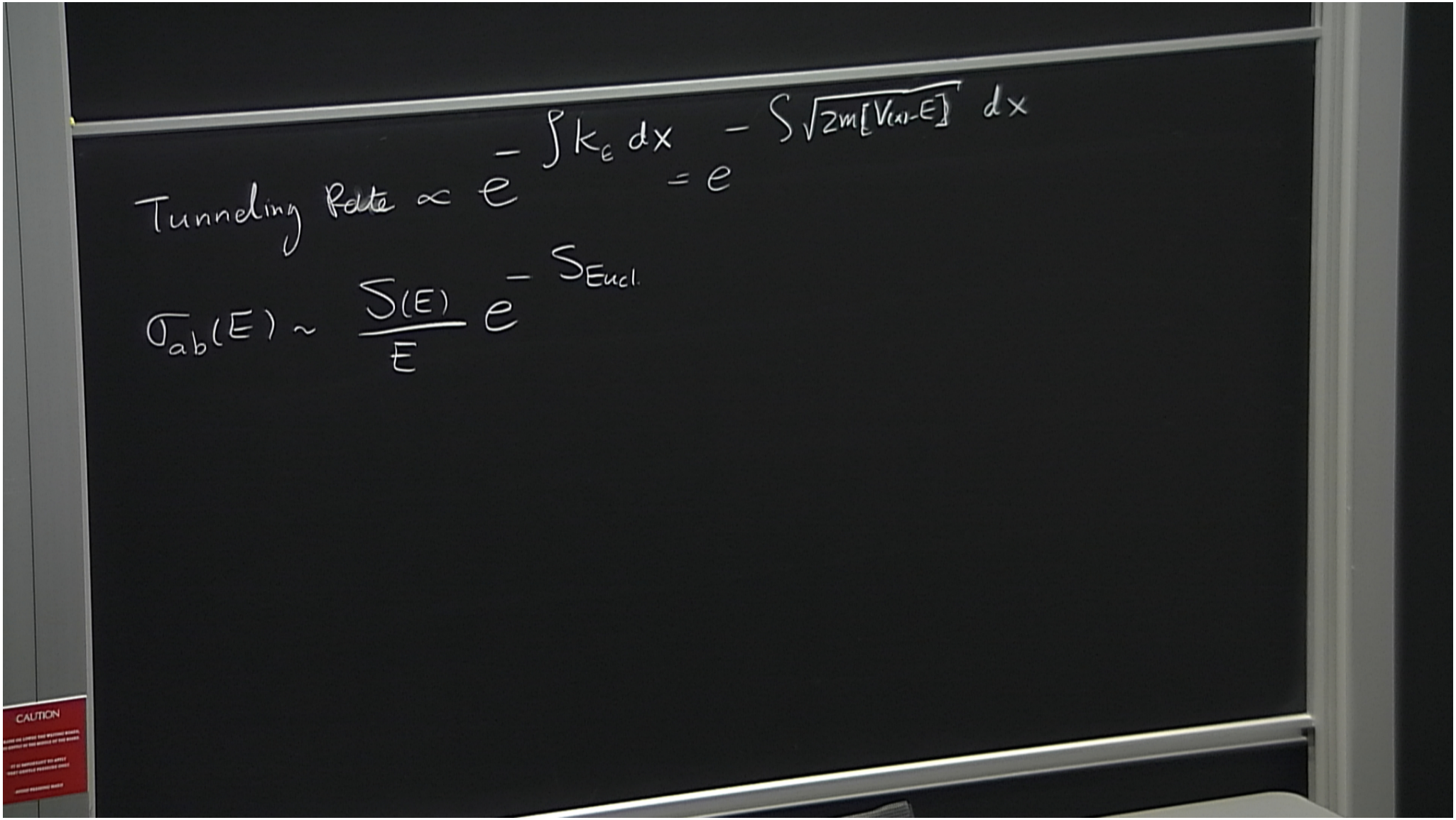
$$+ d\tau \times L_E = \left[-\frac{\left(\frac{dx(\tau)}{d\tau}\right)^2}{2} - V(x)\right] d\tau$$

$$= -\left[\frac{1}{2}\left(\frac{dx}{d\tau}\right)^2 + V(x)\right] d\tau$$

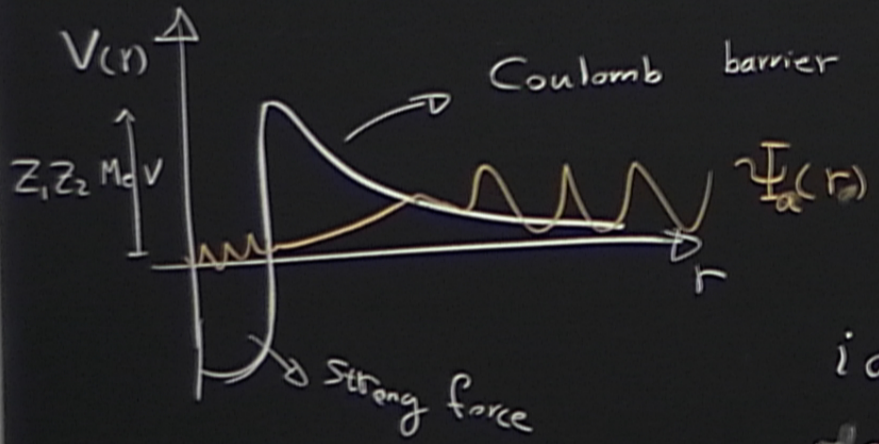

Non-resonant reaction
V(r)
Coulomb barrier
$Z_1 Z_2$ M
$\Psi_a(r_a)$
r
Strong force
Euclidean Action
$\int Dx(t)\, e^{iS[x(t)]}$
$t \to -i\tau$
$\int Dx(\tau)\, e^{-S_E[x(\tau)]}$
$\simeq Qe^{-S_E[x_{cl}]}$
$i\,dt \times L = i\left(\frac{\dot{x}^2}{2} - V(x)\right) dt$
$+ d\tau \times L_E = \left[-\frac{\left(\frac{dx}{d\tau}\right)^2}{2} - V(x)\right] d\tau$
$= -\left[\frac{1}{2}\left(\frac{dx}{d\tau}\right)^2 + V(x)\right] d\tau$


Tunneling Rate $\propto e^{-\int k\,dx} = e^{-\int \sqrt{2m[V(x)-E]}\,dx}$
CAUTION


Tunneling Rate $\propto e^{-\int k_E dx} = e^{-\int \sqrt{2m[V(x)-E]}\, dx}$
CAUTION


Tunneling Rate $\propto e^{-\int k_E\, dx} = e^{-\int \sqrt{2m[V(x)-E]}\, dx}$
$\sigma_{ab}(E) \sim \frac{S(E)}{E} e^{-S_{Eucl.}}$
CAUTION

Non-resonant reaction



$$\eta_{\mu\nu} = \begin{pmatrix} -1 & & & \\ & +1 & & \\ & & +1 & \\ & & & + \end{pmatrix}$$

Euclidean Action

$$\int Dx(t)\, e^{iS[x(t)]}$$

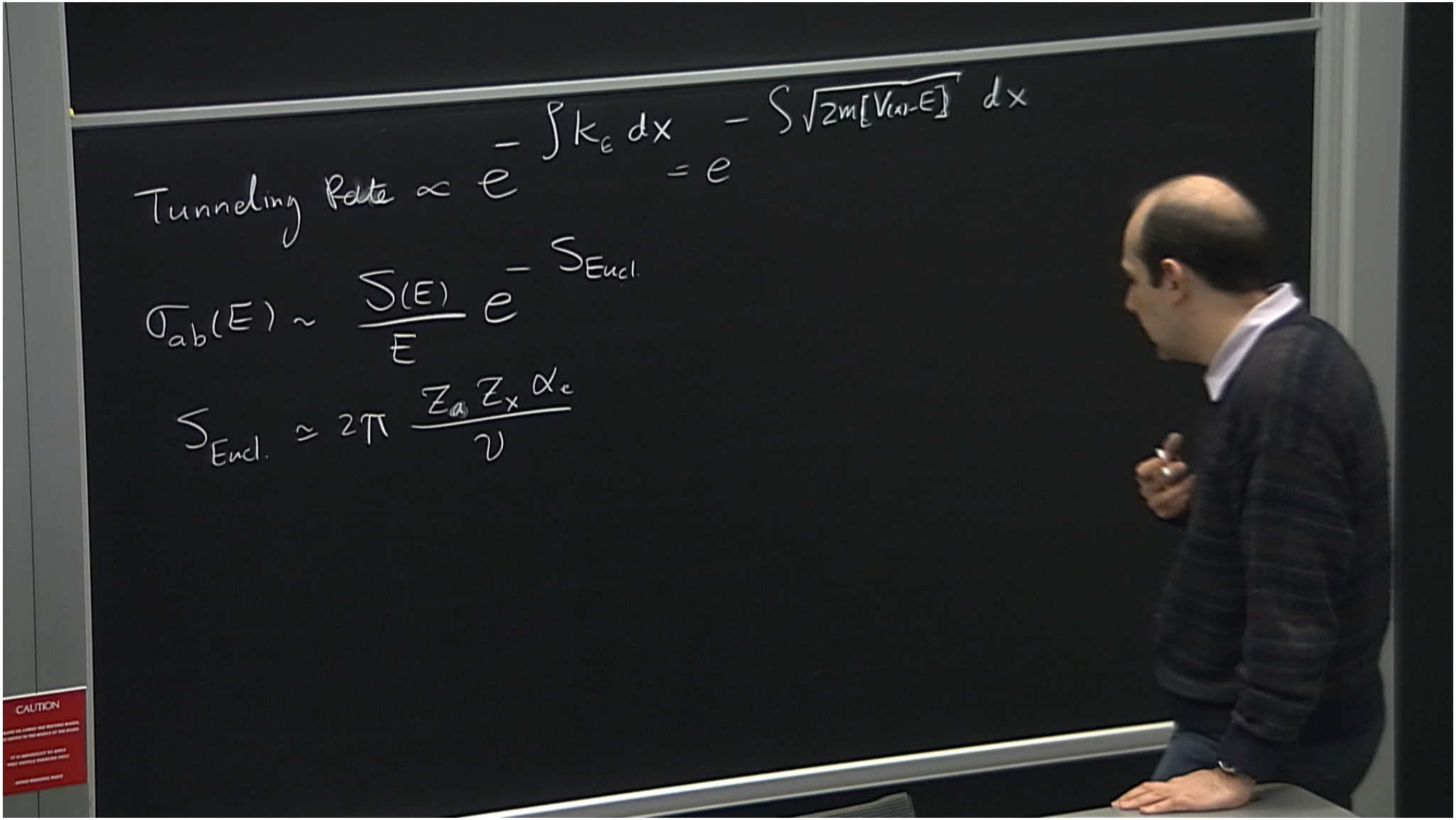
$t \to -i\tau$

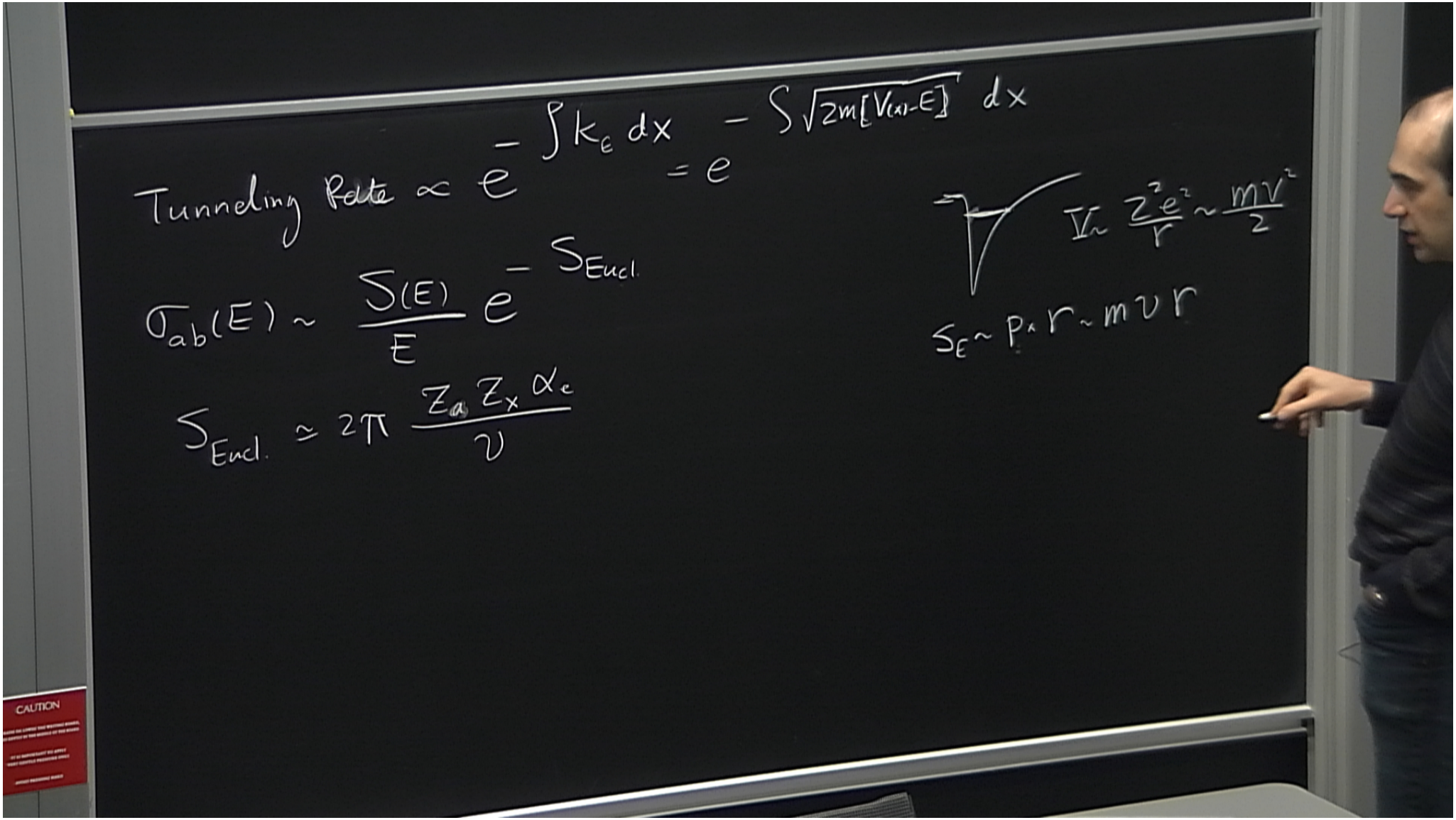
$$\int Dx(\tau)\, e^{-S_E[x(\tau)]} \simeq Qe^{-S_E[x_{cl}]}$$

$$i\,dt \times L = i\left(\frac{\dot{x}^2}{2} - V(x)\right) dt$$

$$+ d\tau \times L_E = \left[-\frac{\left(\frac{dx}{d\tau}\right)^2}{2} - V(x)\right] d\tau$$

$$= -\left[\frac{1}{2}\left(\frac{dx}{d\tau}\right)^2 + V(x)\right] d\tau$$

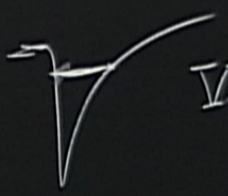

Tunneling Rate $\propto e^{-\int k_E dx} = e^{-\int \sqrt{2m[V(x)-E]}\, dx}$
$\sigma_{ab}(E) \sim \frac{S(E)}{E} e^{-S_{Encl.}}$
$S_{Encl.} \simeq 2\pi \frac{Z_a Z_x \alpha_c}{v}$
CAUTION


Tunneling Rate $\propto e^{-\int k_E dx} = e^{-\int \sqrt{2m[V(x)-E]}\, dx}$
$\sigma_{ab}(E) \sim \frac{S(E)}{E} e^{-S_{Encl.}}$
$S_{Encl.} \simeq 2\pi \frac{Z_a Z_x \alpha_e}{v}$
$V \sim \frac{Z^2 e^2}{r} \sim \frac{mv^2}{2}$
$S_E \sim p \cdot r \sim mvr$
CAUTION

Tunneling Rate $\propto e^{-\int k_E\, dx} = e^{-\int \sqrt{2m[V(x)-E]}\, dx}$

$\sigma_{ab}(E) \sim \frac{S(E)}{E} e^{-S_{Encl.}}$

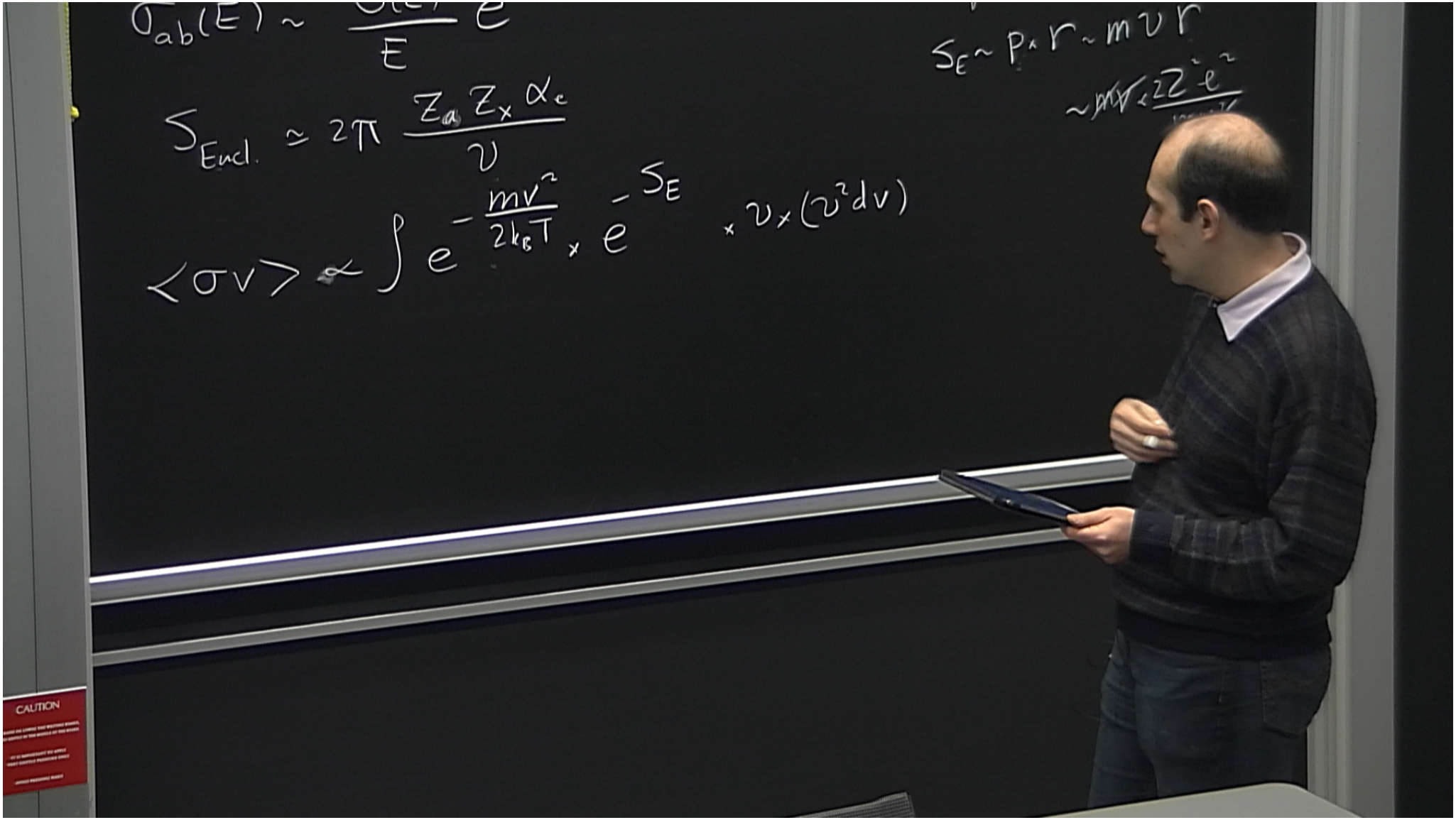
$S_{Encl.} \simeq 2\pi \frac{Z_a Z_x \alpha_c}{v}$

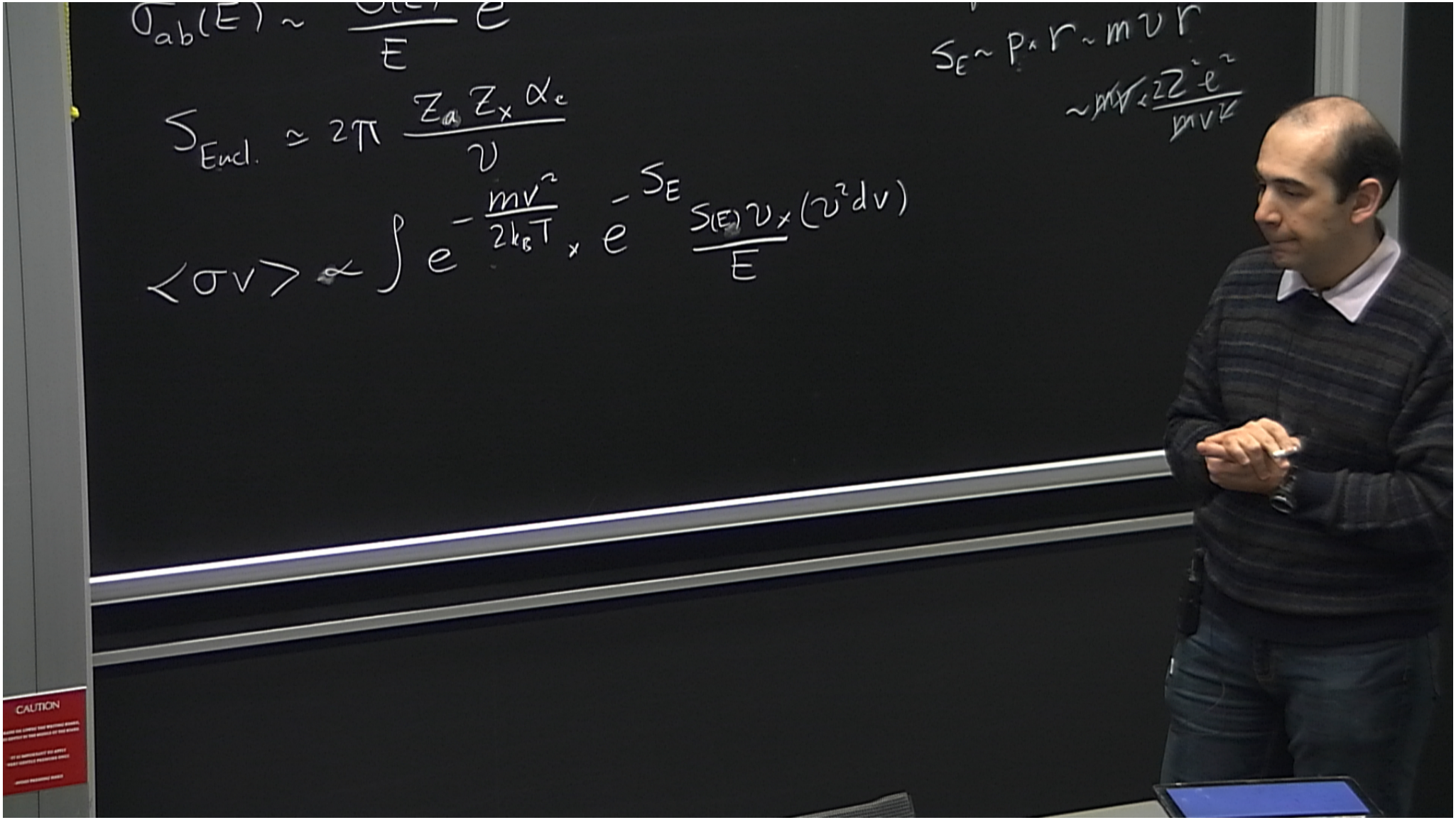


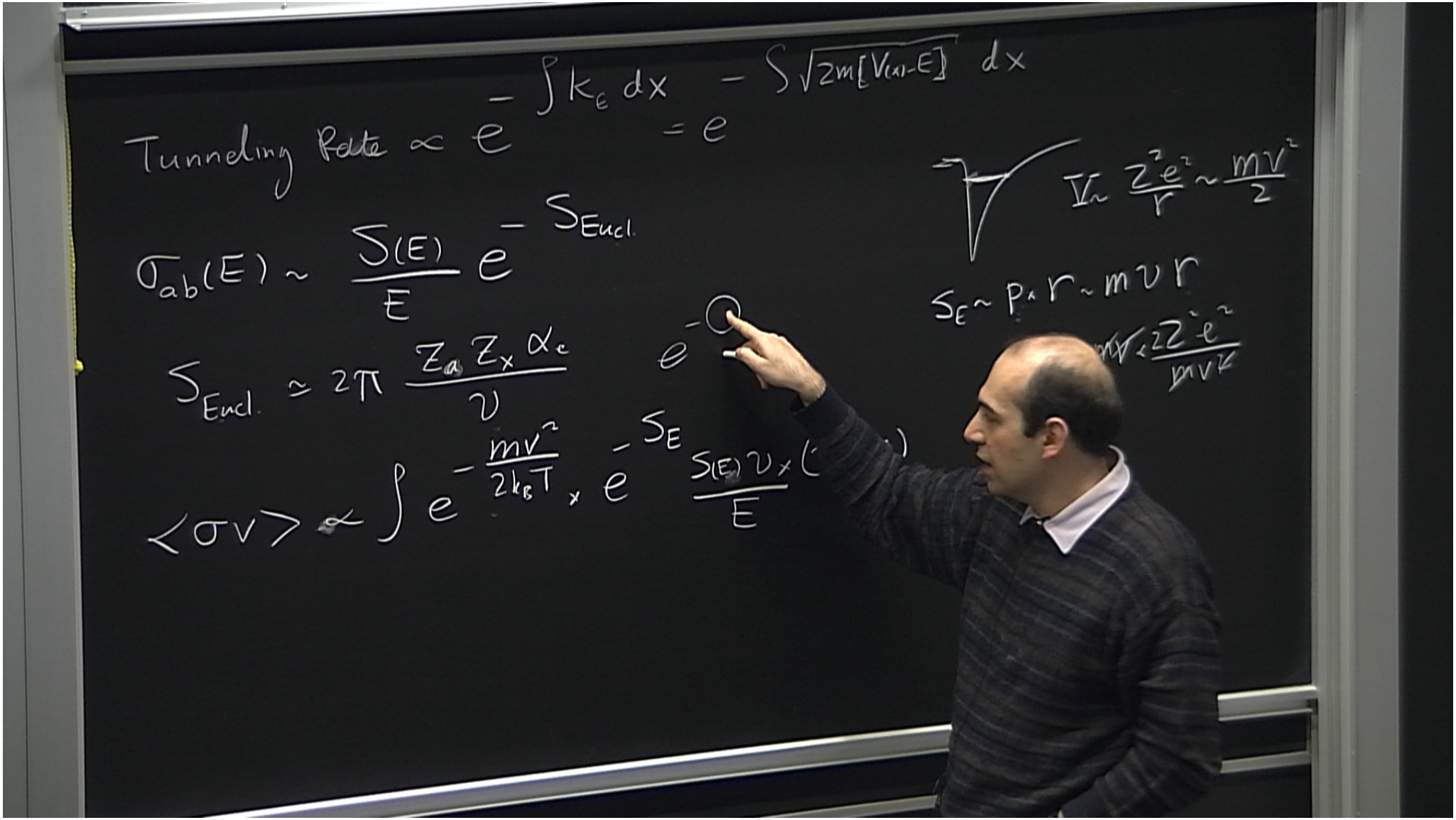
$V \sim \frac{Z^2 e^2}{r} \sim \frac{mv^2}{2}$

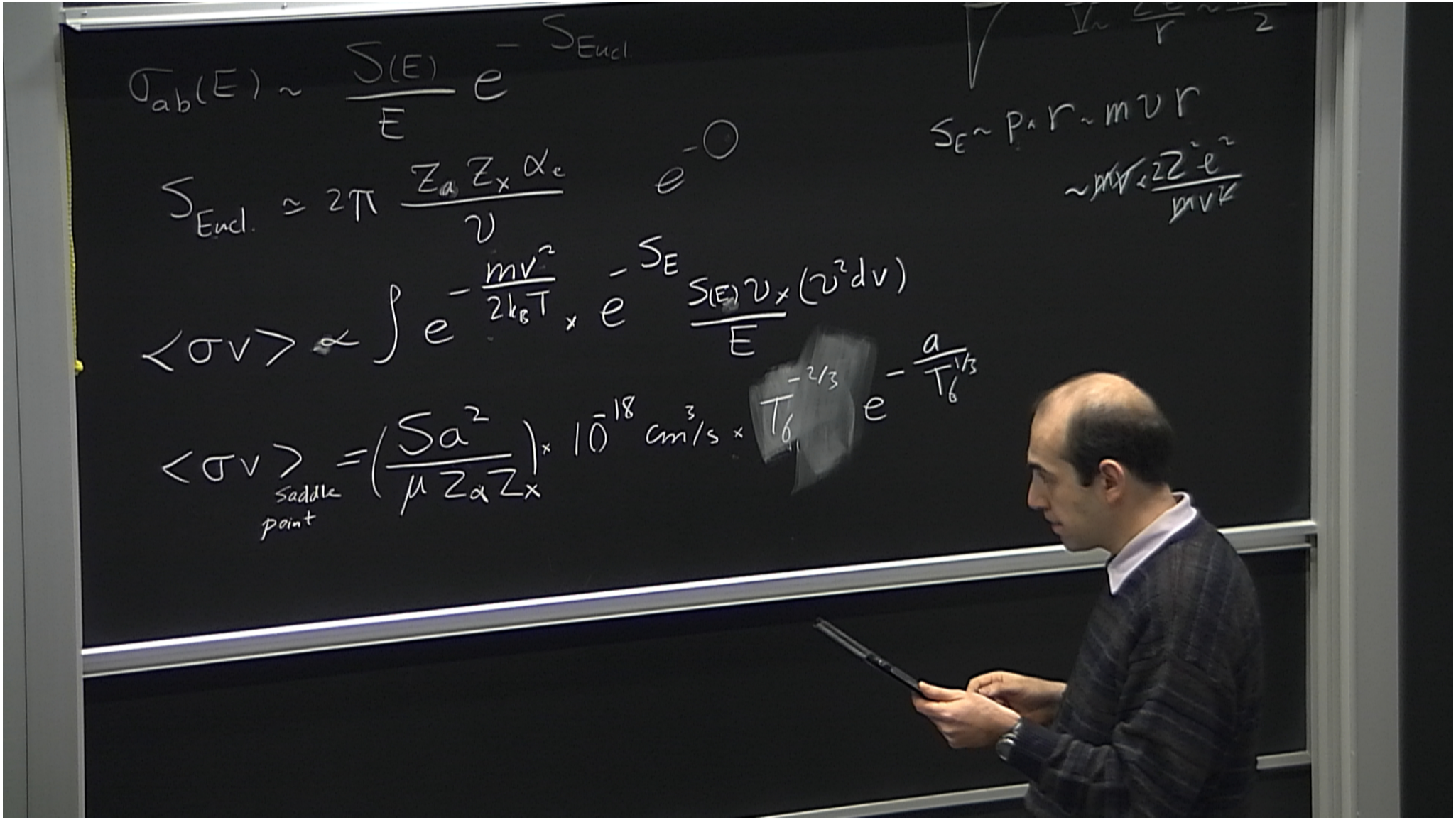
$S_E \sim p \times r \sim mvr$

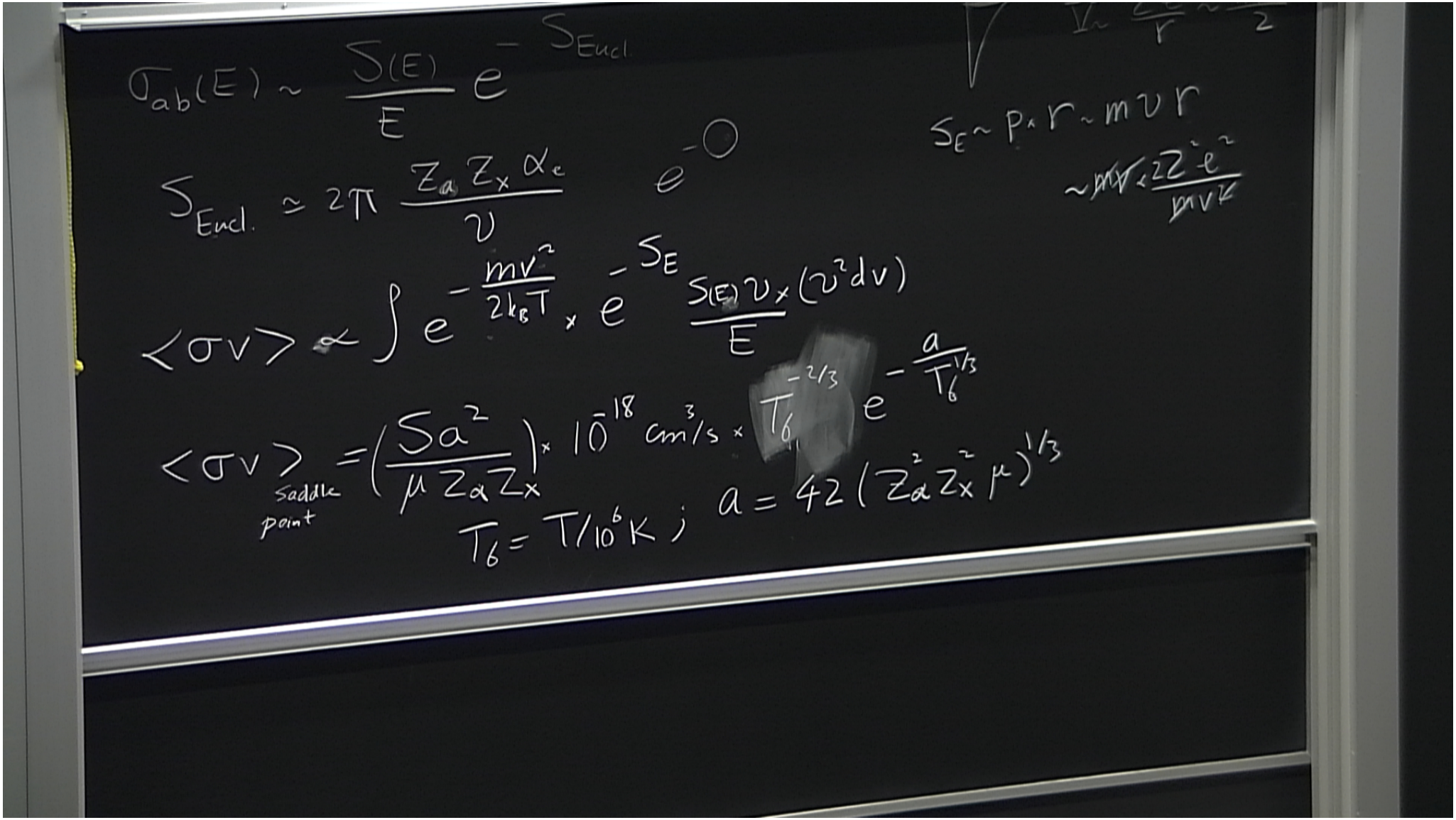
$\sim mvr \frac{2Z^2 e^2}{mv^2}$


$\sigma_{ab}(E) \sim \frac{S(E)}{E} e^{-\sqrt{E_G/E}}$
$S_{Encl.} \simeq 2\pi \frac{Z_a Z_x \alpha_e}{v}$
$\langle \sigma v \rangle \propto \int e^{-\frac{mv^2}{2k_B T}} \times e^{-S_E} \times v \times (v^2 dv)$
$S_E \sim p \times r \sim m v r$
$\sim \hbar \times \frac{Z Z' e^2}{\hbar v}$
CAUTION


$\sigma_{ab}(E) \sim \frac{S(E)}{E} e^{-\frac{S_E}{E}}$
$S_{Encl.} \simeq 2\pi \frac{Z_a Z_x \alpha_c}{v}$
$\langle \sigma v \rangle \propto \int e^{-\frac{mv^2}{2k_B T}} \times e^{-\frac{S_E}{E}} \frac{S(E) v}{E} (v^2 dv)$
$S_E \sim p \times r \sim m v r$
$\sim \frac{Z Z' e^2}{m v^2}$
CAUTION


Tunneling Rate ∝ e^{-∫ k_E dx} = e^{-∫ √(2m[V(x)-E]) dx}
σ_ab(E) ~ S(E)/E e^{-S_Eucl.}
S_Eucl. ≃ 2π Z_a Z_x α_e / v
<σv> ∝ ∫ e^{-mv²/2k_BT} × e^{-S_E} S(E) v × (
V ~ Z²e²/r ~ mv²/2
S_E ~ p × r ~ m v r
mv² < 2Z²e²/mv²


$\sigma_{ab}(E) \sim \frac{S(E)}{E} e^{-S_{Eucl}}$
$S_{Eucl.} \simeq 2\pi \frac{Z_a Z_x \alpha_c}{v}$
$e^{-\bigcirc}$
$S_E \sim p \times r \sim m v r$
$\sim \frac{Z Z' e^2}{m v^2}$
$\langle \sigma v \rangle \propto \int e^{-\frac{mv^2}{2k_B T}} \times e^{-S_E} \frac{S(E) v \times (v^2 dv)}{E}$
$\langle \sigma v \rangle_{\text{Saddle point}} = \left(\frac{S a^2}{\mu Z_a Z_x}\right) \times 10^{-18}\ cm^3/s \times T_6^{-2/3} e^{-\frac{a}{T_6^{1/3}}}$


$\sigma_{ab}(E) \sim \frac{S(E)}{E} e^{-S_{Encl}}$
$S_{Encl.} \simeq 2\pi \frac{Z_a Z_x \alpha_c}{v}$
$e^{-\bigcirc}$
$S_E \sim p \times r \sim m v r$
$\sim \frac{Z^2 e^2}{mv^2}$
$\langle \sigma v \rangle \propto \int e^{-\frac{mv^2}{2k_B T}} \times e^{-S_E} \frac{S(E) v}{E} \times (v^2 dv)$
$\langle \sigma v \rangle_{\text{saddle point}} = \left(\frac{S a^2}{\mu Z_a Z_x}\right) \times 10^{-18}\ cm^3/s \times T_6^{-2/3} e^{-\frac{a}{T_6^{1/3}}}$
$T_6 = T/10^6 K$; $a = 42 (Z_a^2 Z_x^2 \mu)^{1/3}$

Tunneling Rate $\propto e^{-\int k_E\, dx} = e^{-\int \sqrt{2m[V(x)-E]}\, dx}$

$\sigma_{ab}(E) \sim \frac{S(E)}{E} e^{-S_{Encl.}}$

$S_{Encl.} \simeq 2\pi \frac{Z_a Z_x \alpha_e}{v}$ $\quad e^{-\bigcirc}$

$\langle \sigma v \rangle \propto \int e^{-\frac{mv^2}{2k_B T}} \times e^{-S_E} \frac{S(E)}{E} v \times (v^2 dv)$

$\langle \sigma v \rangle_{\substack{\text{Saddle} \\ \text{point}}} = \left(\frac{S a^2}{\mu Z_a Z_x}\right) \times 10^{-18}\ cm^3/s \times T_6^{-2/3} e^{-\frac{a}{T_6^{1/3}}}$

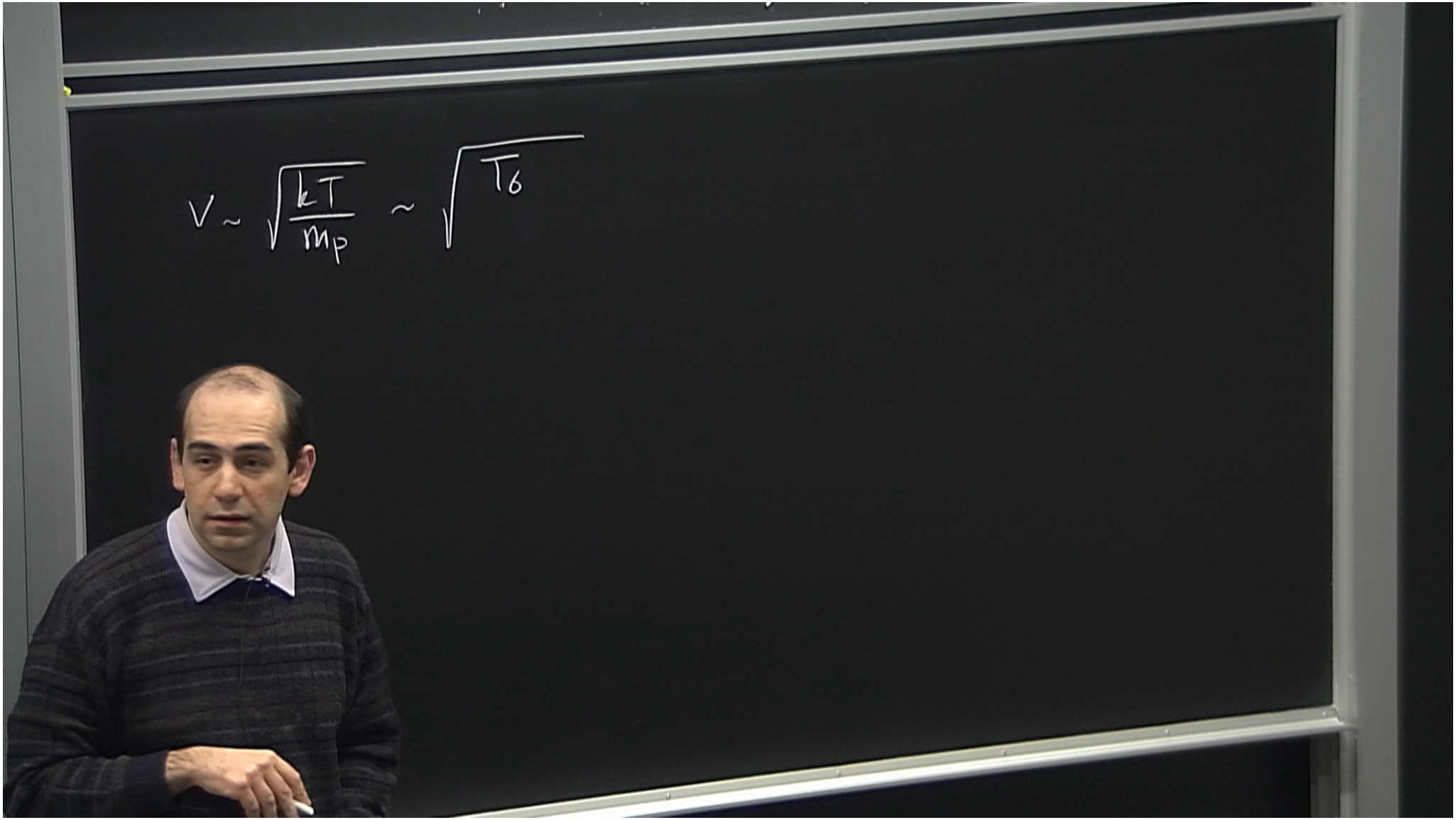
$T_6 = T/10^6 K$; $a = 42 (Z_a^2 Z_x^2 \mu)^{1/3}$

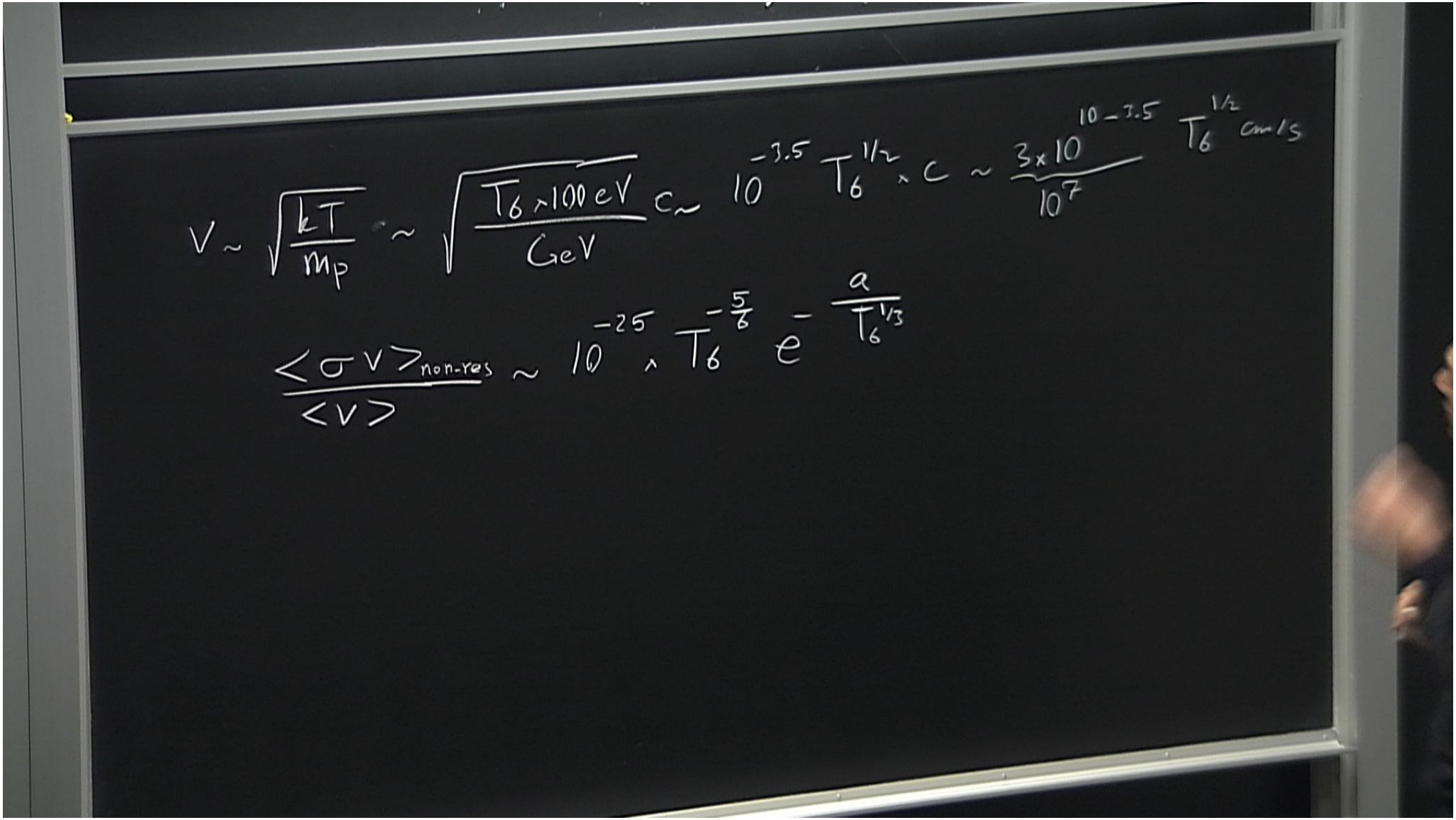


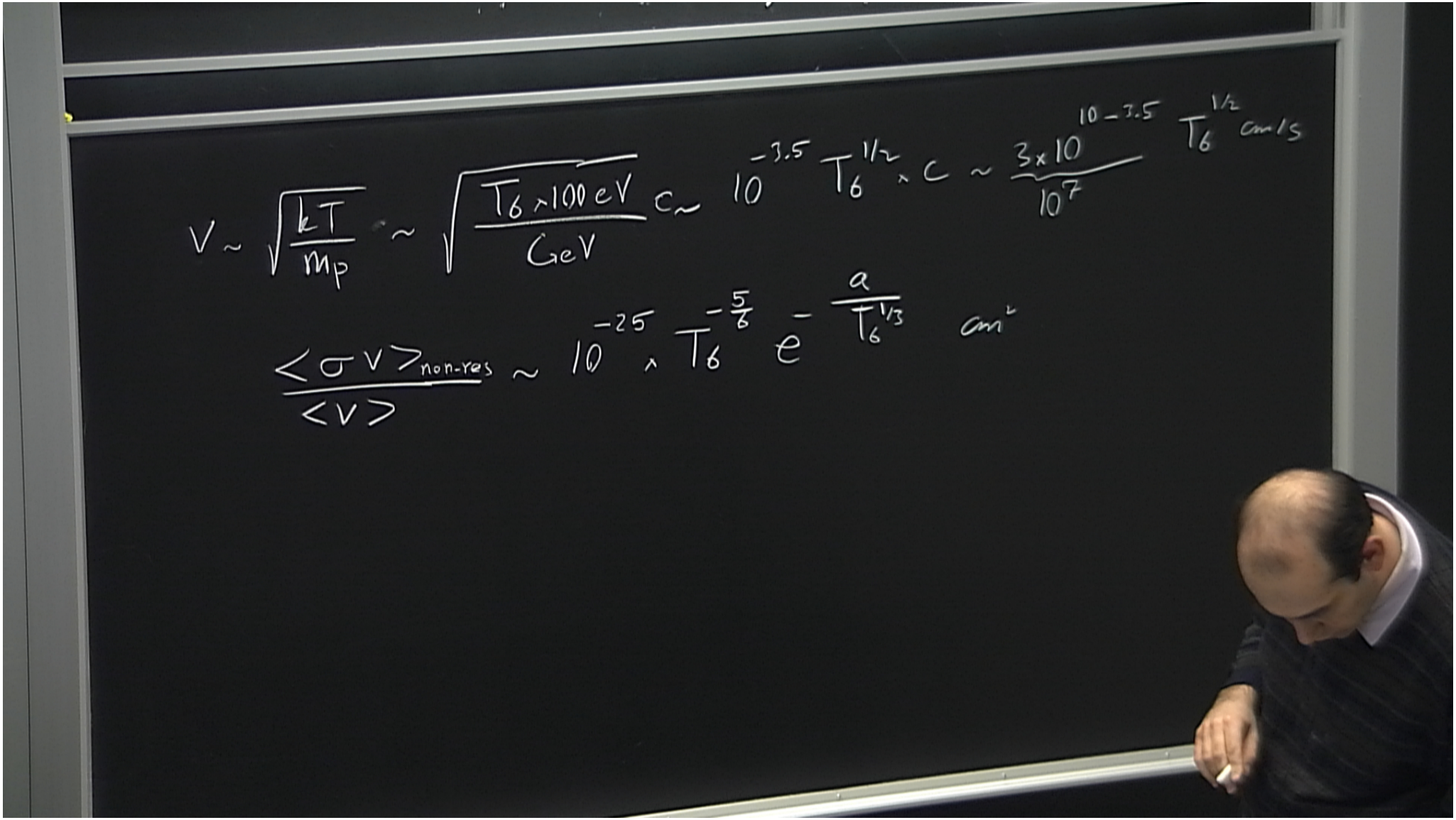
$V \sim \frac{Z^2 e^2}{r} \sim \frac{mv^2}{2}$

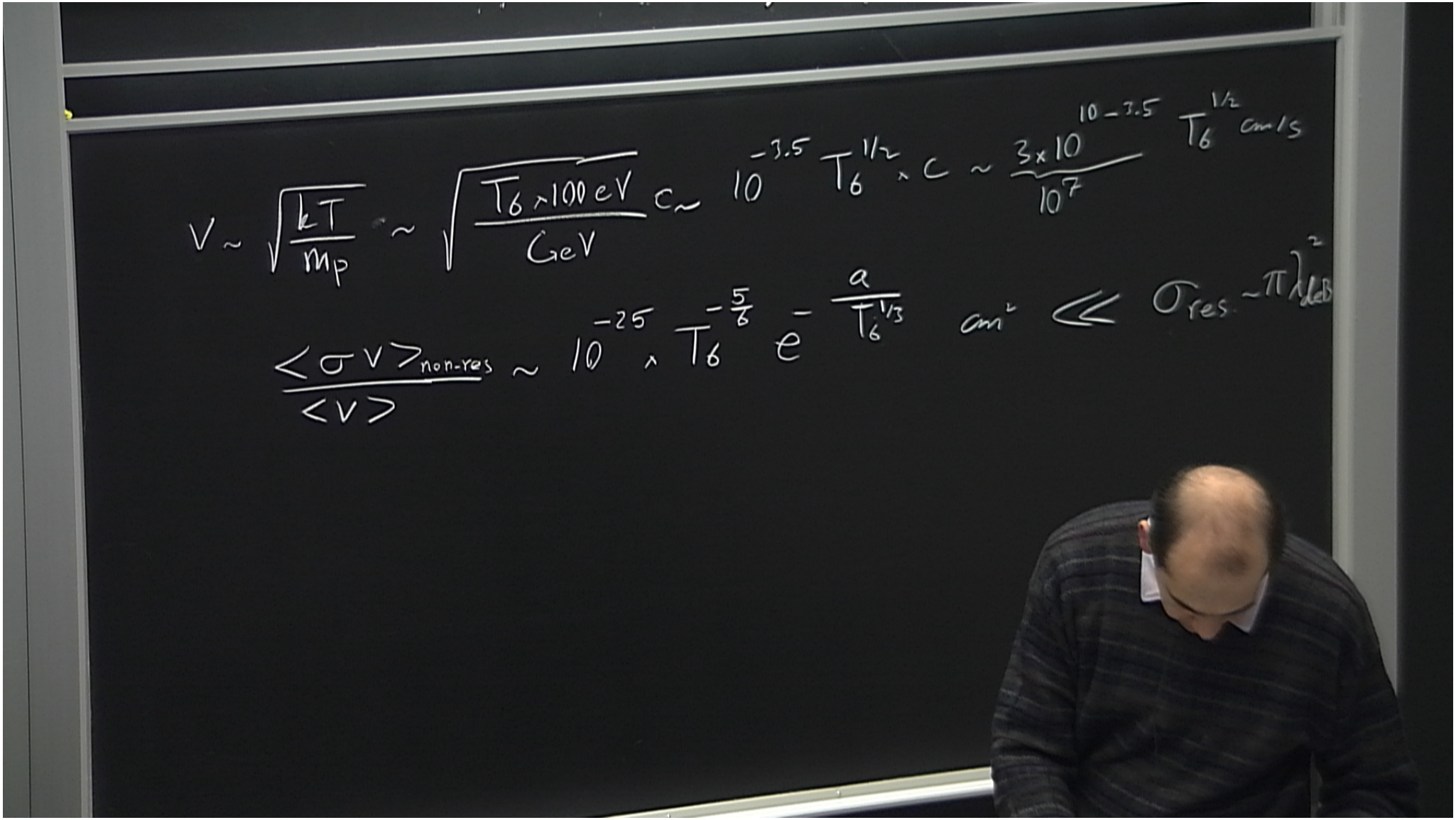
$S_E \sim p \times r \sim mvr$

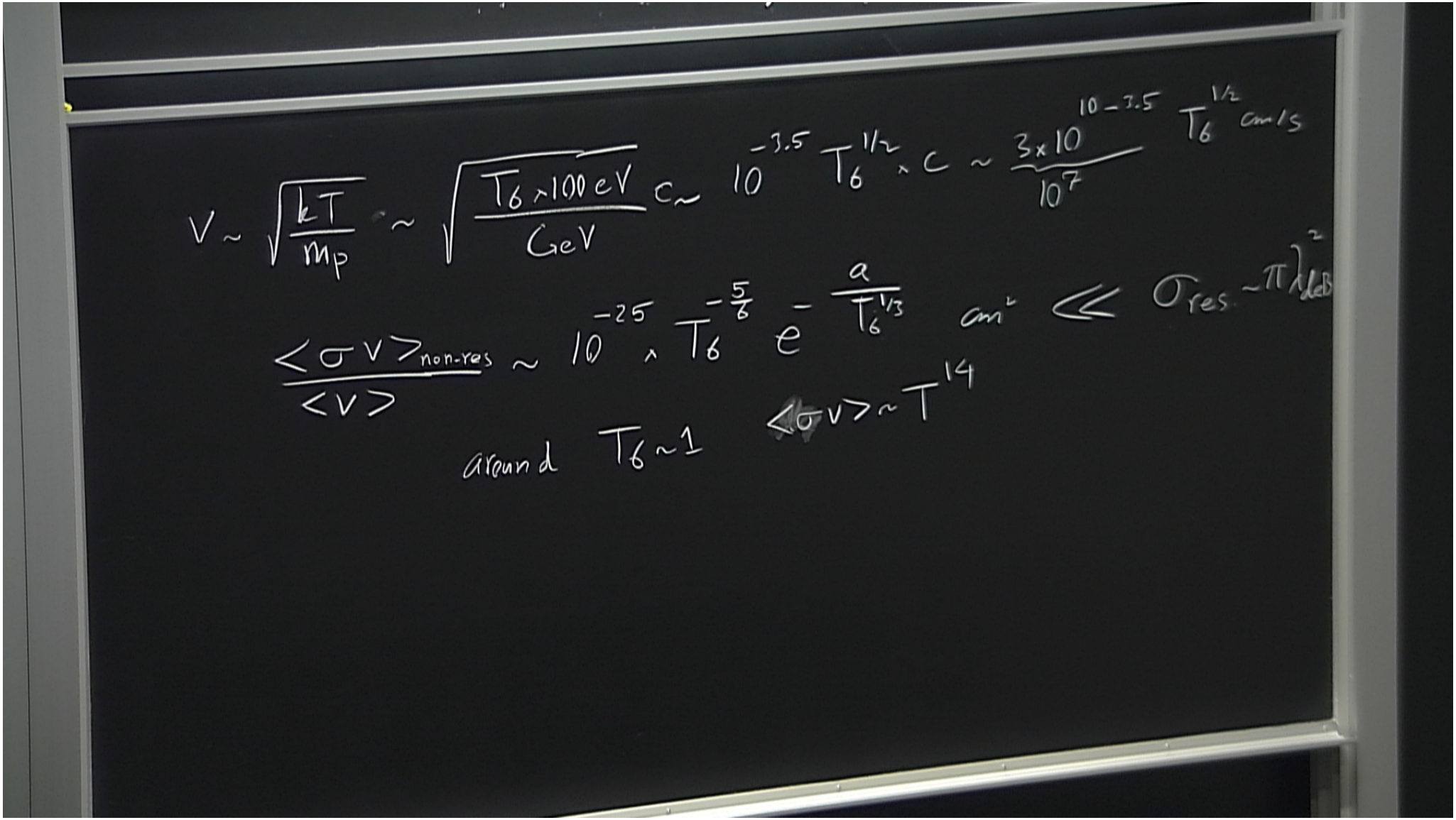
$\sim mvr < \frac{ZZ' e^2}{mv^2}$

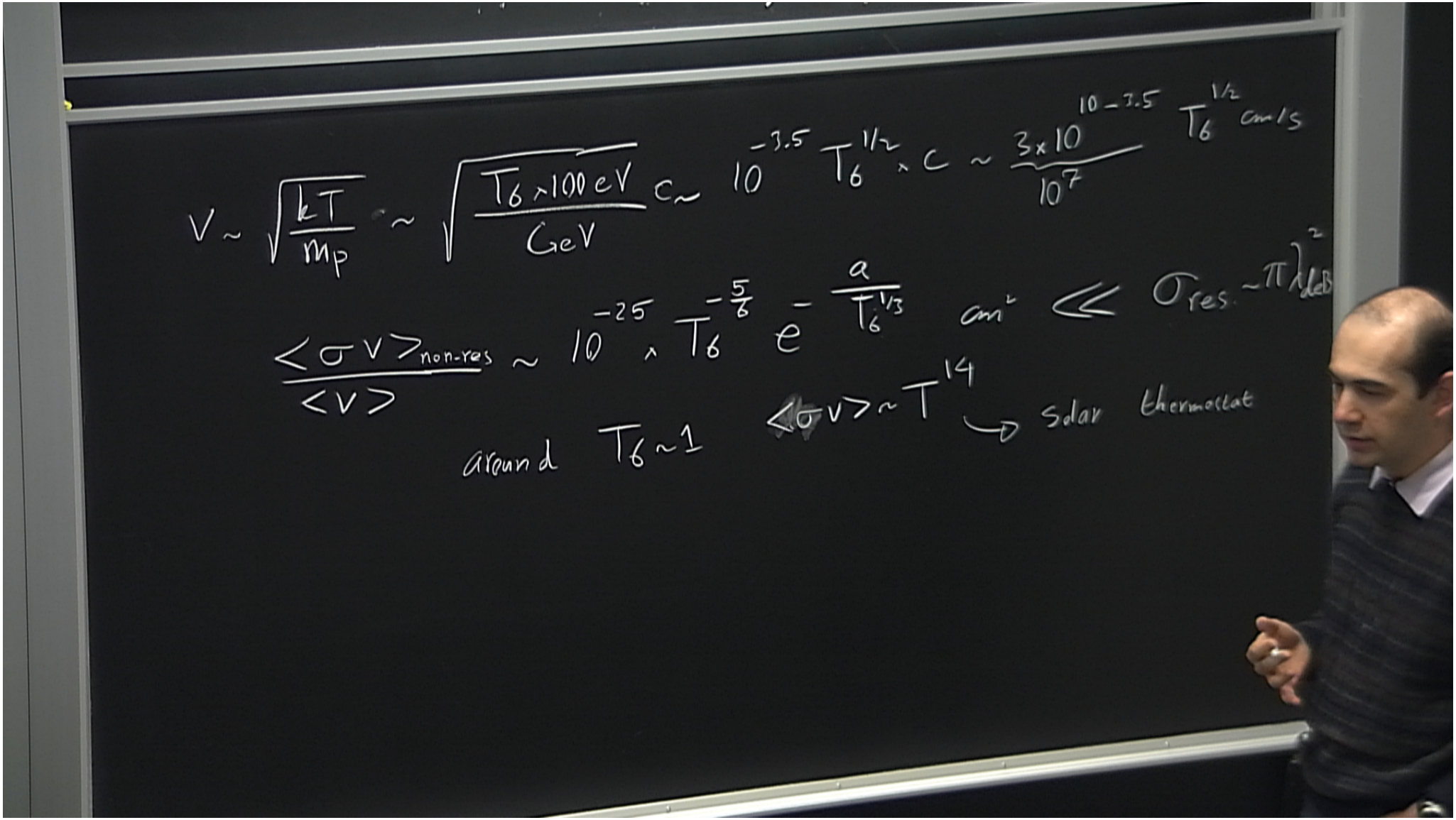

$V \sim \sqrt{\frac{kT}{m_p}} \sim \sqrt{T_6}$

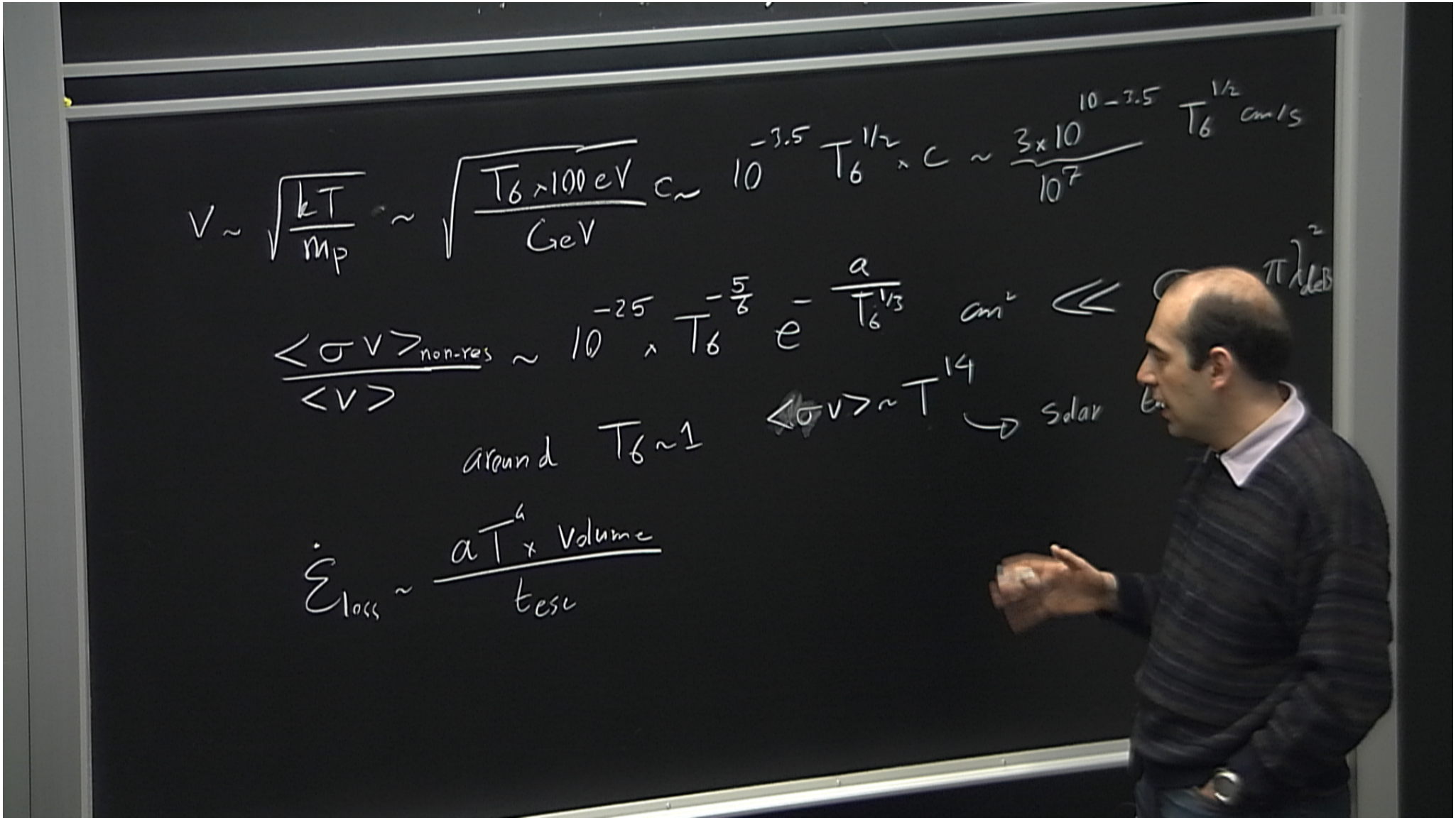

$v \sim \sqrt{\frac{kT}{m_p}} \sim \sqrt{\frac{T_6 \sim 100\,eV}{GeV}}\, c \sim 10^{-3.5} T_6^{1/2} \times c \sim \frac{3\times 10^{10-3.5}}{10^7} T_6^{1/2}\ cm/s$
$\frac{\langle \sigma v \rangle_{non\text{-}res}}{\langle v \rangle} \sim 10^{-25} \times T_6^{-\frac{5}{6}}\, e^{-\frac{a}{T_6^{1/3}}}$


$v \sim \sqrt{\frac{kT}{m_p}} \sim \sqrt{\frac{T_6 \sim 100\,eV}{GeV}}\, c \sim 10^{-3.5} T_6^{1/2} \times c \sim \frac{3 \times 10^{10-3.5}}{10^7} T_6^{1/2}$ cm/s
$\frac{\langle \sigma v \rangle_{non\text{-}res}}{\langle v \rangle} \sim 10^{-25} \times T_6^{-\frac{5}{6}} e^{-\frac{a}{T_6^{1/3}}}$ cm^2


$v \sim \sqrt{\frac{kT}{m_p}} \sim \sqrt{\frac{T_6 \times 100\,eV}{GeV}}\, c \sim 10^{-3.5} T_6^{1/2} \times c \sim \frac{3 \times 10^{10-3.5}}{10^7} T_6^{1/2}\ cm/s$
$\frac{\langle \sigma v \rangle_{non\text{-}res}}{\langle v \rangle} \sim 10^{-25} \times T_6^{-\frac{5}{6}} e^{-\frac{a}{T_6^{1/3}}}\ cm^2 \ll \sigma_{res} \sim \pi \lambda_{deB}^2$

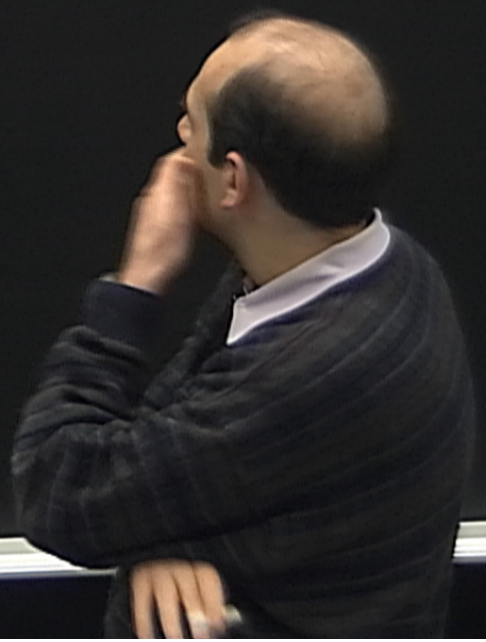

$v \sim \sqrt{\frac{kT}{m_p}} \sim \sqrt{\frac{T_6 \sim 100\,eV}{GeV}}\, c \sim 10^{-3.5} T_6^{1/2} \times c \sim \frac{3\times 10^{10-3.5}}{10^7} T_6^{1/2}$ cm/s
$\frac{\langle \sigma v \rangle_{non\text{-}res}}{\langle v \rangle} \sim 10^{-25} \times T_6^{-\frac{5}{6}} e^{-\frac{a}{T_6^{1/3}}}$ cm^2 $\ll \sigma_{res} \sim \pi \lambda_{deB}^2$
around $T_6 \sim 1$ $\langle \sigma v \rangle \sim T^{14}$


$v \sim \sqrt{\frac{kT}{m_p}} \sim \sqrt{\frac{T_6 \times 100\,eV}{GeV}} c \sim 10^{-3.5} T_6^{1/2} \times c \sim \frac{3 \times 10^{10-3.5}}{10^7} T_6^{1/2}$ cm/s
$\frac{\langle \sigma v \rangle_{non\text{-}res}}{\langle v \rangle} \sim 10^{-25} \times T_6^{-\frac{5}{6}} e^{-\frac{a}{T_6^{1/3}}}$ cm^2 $\ll \sigma_{res} \sim \pi \lambda_{deB}^2$
around $T_6 \sim 1$ $\langle \sigma v \rangle \sim T^{14}$ → solar thermostat


$v \sim \sqrt{\frac{kT}{m_p}} \sim \sqrt{\frac{T_6 \times 100\,eV}{GeV}}\, c \sim 10^{-3.5} T_6^{1/2} \times c \sim \frac{3\times 10^{10-3.5}}{10^7} T_6^{1/2}\ cm/s$
$\frac{\langle \sigma v \rangle_{non\text{-}res}}{\langle v \rangle} \sim 10^{-25} \times T_6^{-\frac{5}{6}} e^{-\frac{a}{T_6^{1/3}}}\ cm^2 \ll \pi \lambda_{deB}^2$
around $T_6 \sim 1$ $\langle \sigma v \rangle \sim T^{14}$ → solar
$\dot{\varepsilon}_{loss} \sim \frac{a T^4 \times Volume}{t_{esc}}$

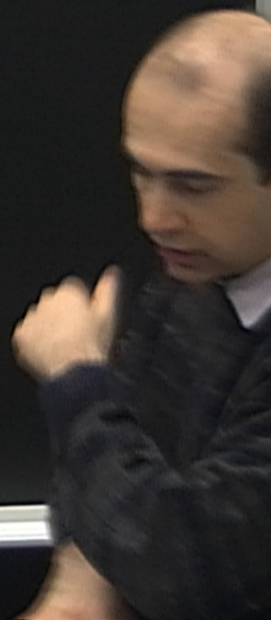
$$\int \sigma_{res}(E)\, dE \sim \Gamma^{-2} \int \frac{dE}{(E-E_r)^2 + (\Gamma/2)^2} = \frac{2\pi}{\Gamma}$$

$$\langle \sigma v \rangle_{res.}$$



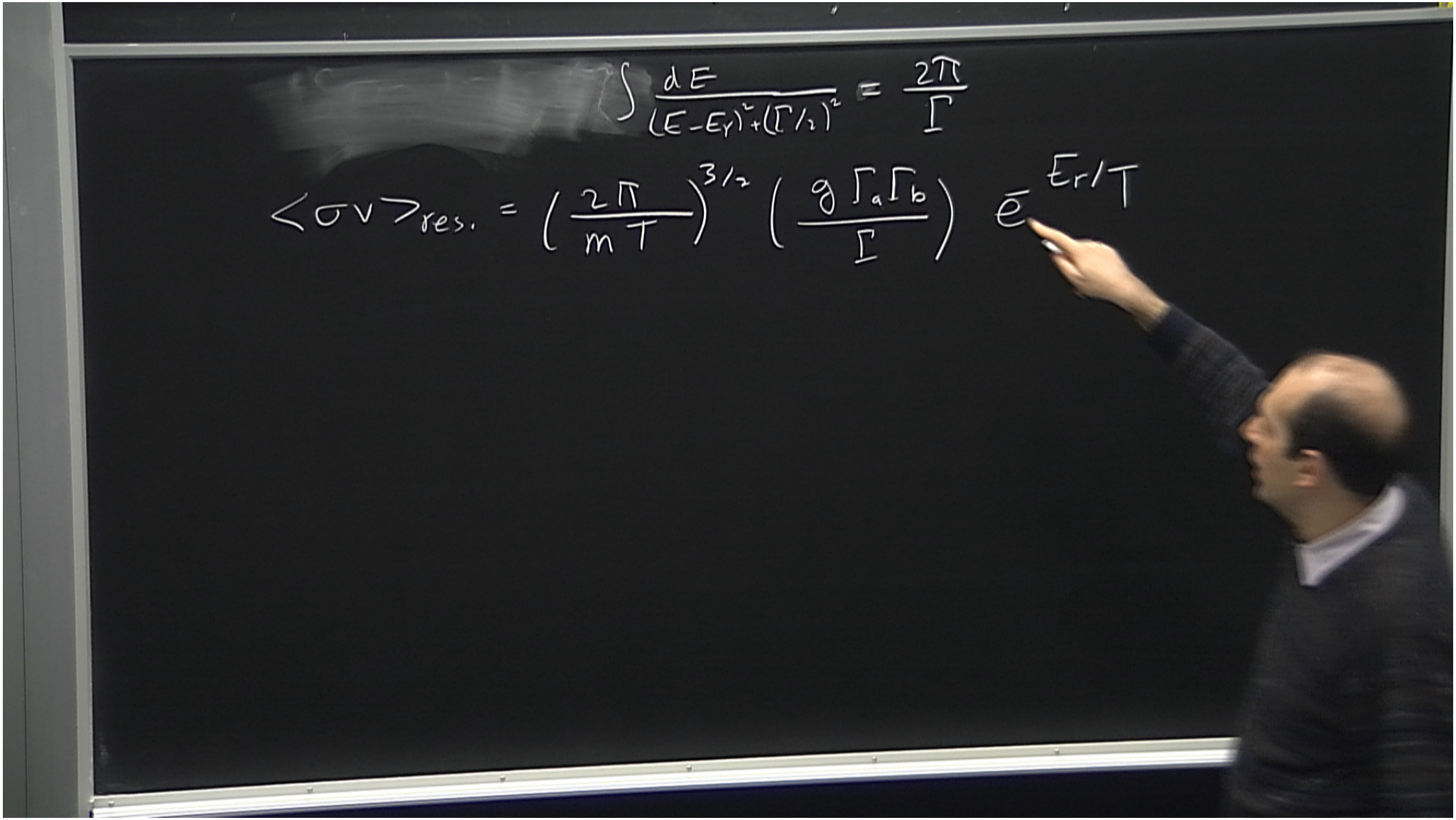
$$\int \sigma_{res}(E)\, dE \sim \Gamma^2 \int \frac{dE}{(E-E_r)^2+(\Gamma/2)^2} = \frac{2\pi}{\Gamma}$$

$$\langle \sigma v \rangle_{res.} = \left(\frac{2\pi}{mT}\right)^{3/2} \left(\frac{g\,\Gamma_a \Gamma_b}{\Gamma}\right) e^{E_r/T}$$



$$\int \frac{dE}{(E-E_r)^2+(\Gamma/2)^2} = \frac{2\pi}{\Gamma}$$

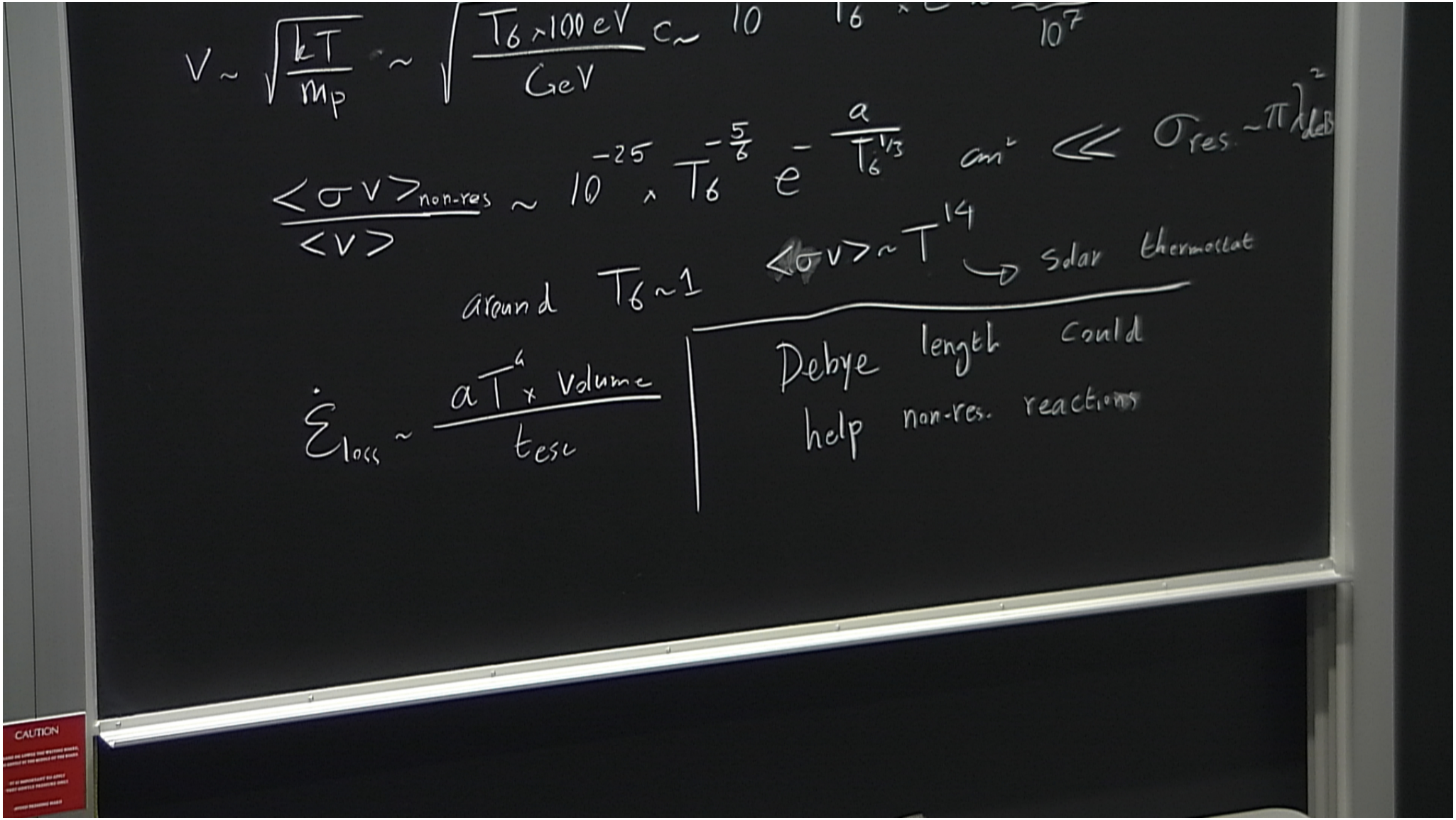
$$\langle \sigma v \rangle_{res.} = \left(\frac{2\pi}{mT}\right)^{3/2} \left(\frac{g\,\Gamma_a \Gamma_b}{\Gamma}\right) e^{E_r/T}$$



$$\int \frac{dE}{(E-E_r)^2+(\Gamma/2)^2} = \frac{2\pi}{\Gamma}$$

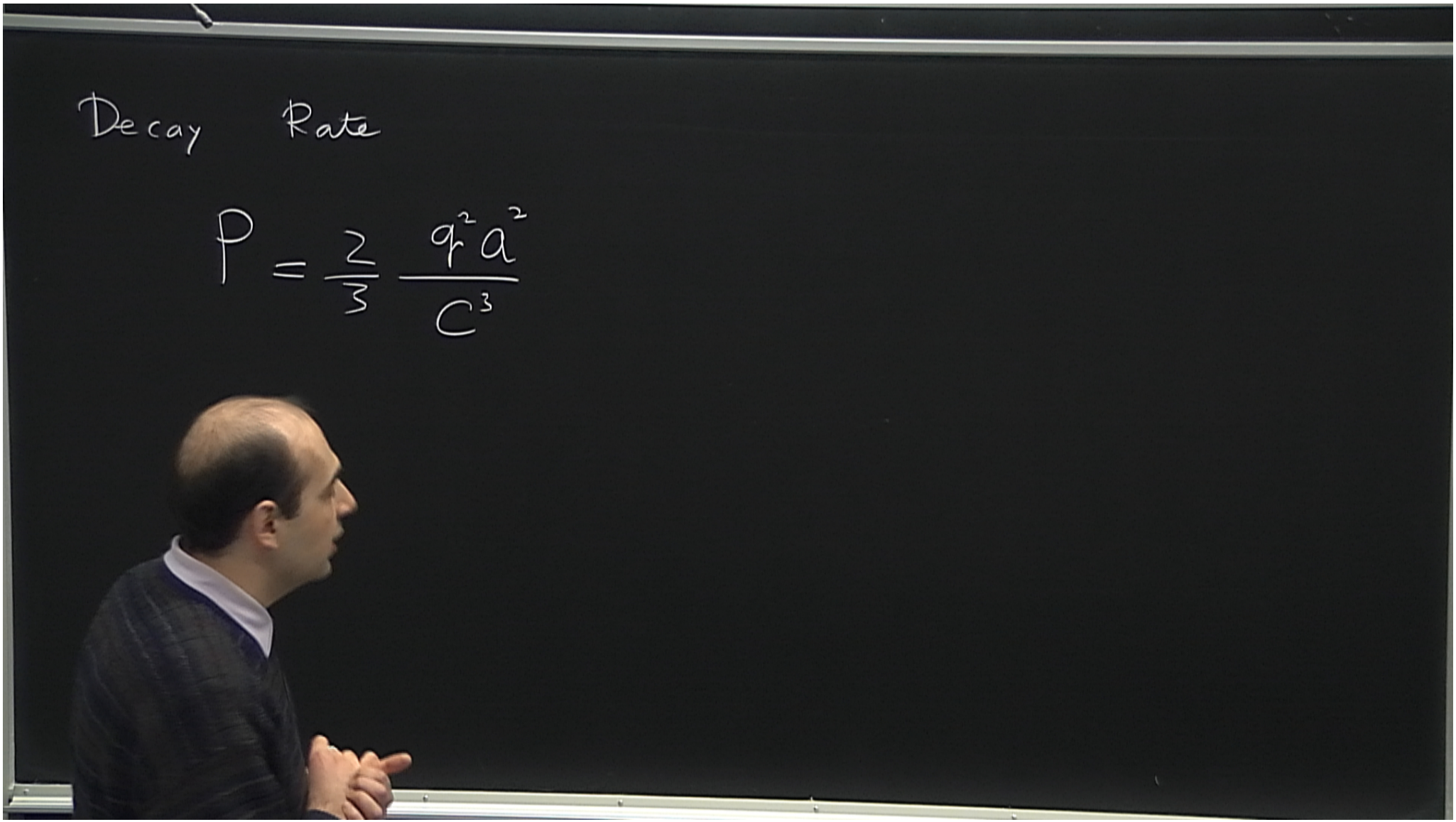
$$\langle \sigma v \rangle_{res.} = \left(\frac{2\pi}{mT}\right)^{3/2} \left(\frac{g\,\Gamma_a \Gamma_b}{\Gamma}\right) e^{E_r/T}$$

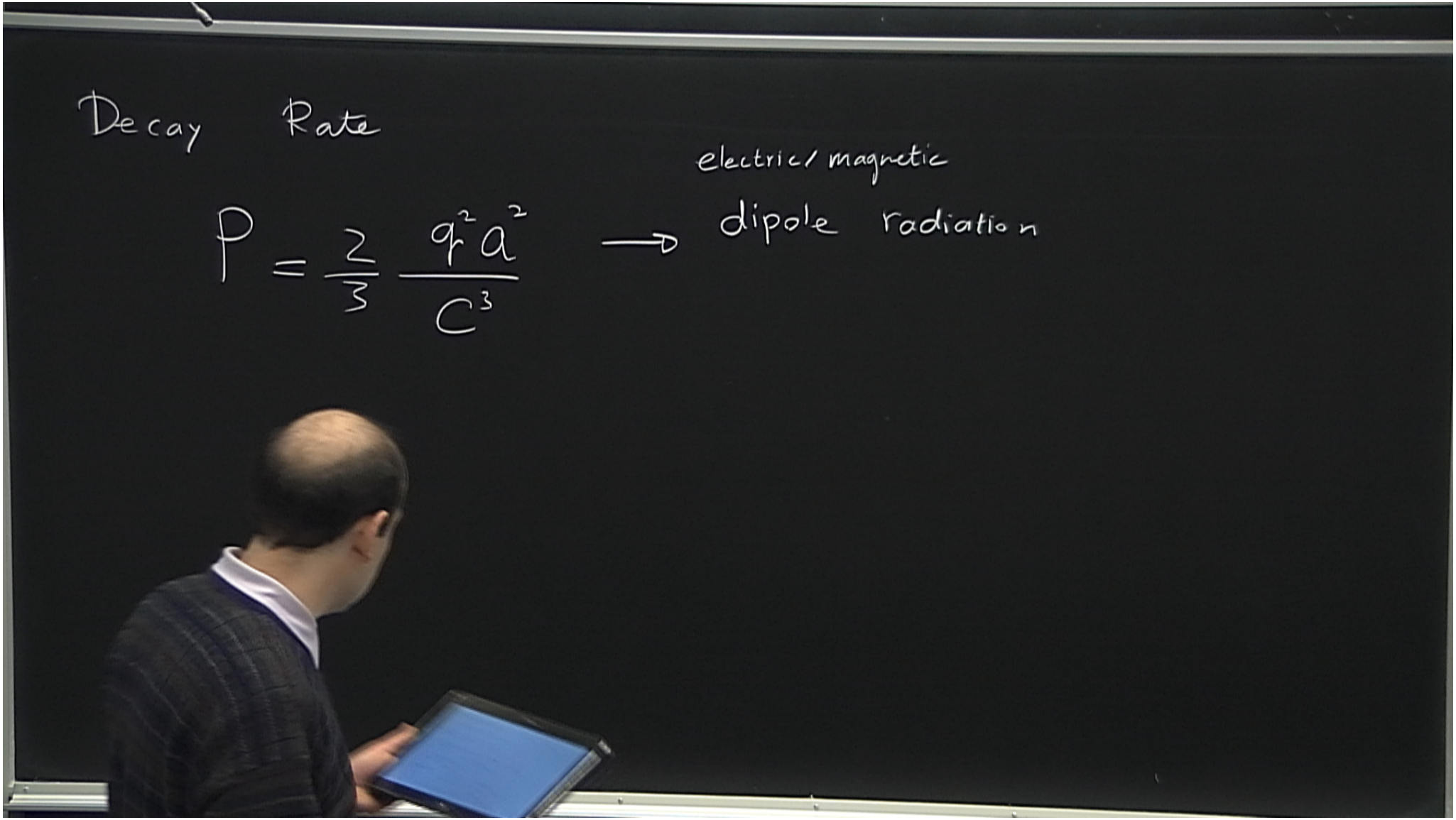
$$\sim 10^{-13}\ \mathrm{cm^3/s} \times e^{-E_r/T} \quad \text{for } T \sim 10^9\ \mathrm{K}$$

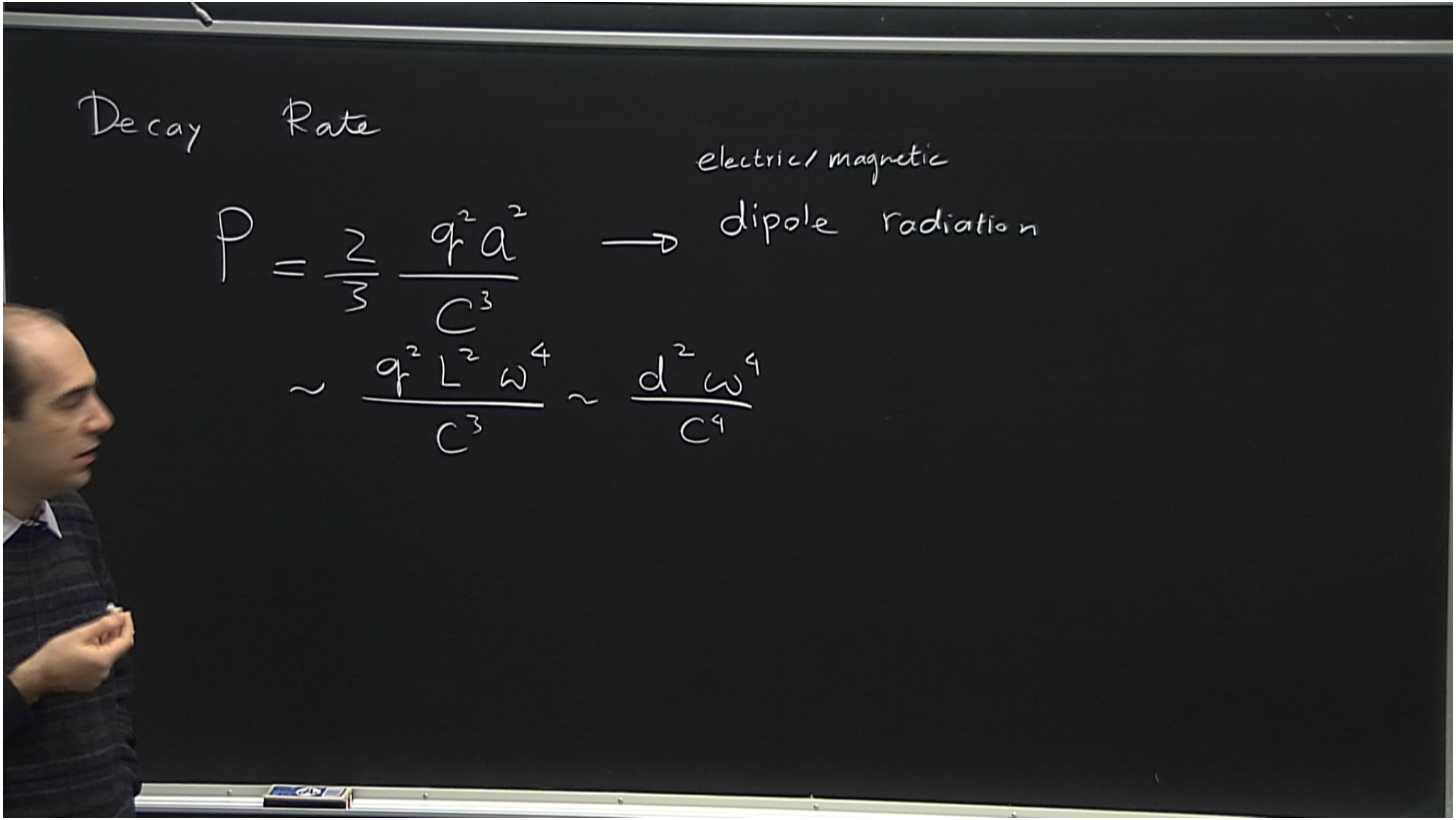

$v \sim \sqrt{\frac{kT}{m_p}} \sim \sqrt{\frac{T_6 \times 100\,eV}{GeV}} c \sim 10$
10^7
$\frac{\langle \sigma v \rangle_{non\text{-}res}}{\langle v \rangle} \sim 10^{-25} \times T_6^{-\frac{5}{6}} e^{-\frac{a}{T_6^{1/3}}}\ cm^2 \ll \sigma_{res} \sim \pi \lambda_{deB}^2$
around $T_6 \sim 1$
$\langle \sigma v \rangle \sim T^{14}$
↳ Solar thermostat
$\dot{\varepsilon}_{loss} \sim \frac{a T^4 \times Volume}{t_{esc}}$
Debye length could help non-res. reactions
CAUTION

Decay Rate

$$P = \frac{2}{3}\frac{q^2 a^2}{c^3}$$




Decay Rate
electric/magnetic
$P = \frac{2}{3}\frac{q^2 a^2}{c^3}$
dipole radiation


Decay Rate
electric/magnetic
$P = \frac{2}{3}\frac{q^2 a^2}{c^3}$ → dipole radiation
$\sim \frac{q^2 L^2 \omega^4}{c^3} \sim \frac{d^2 \omega^4}{c^4}$

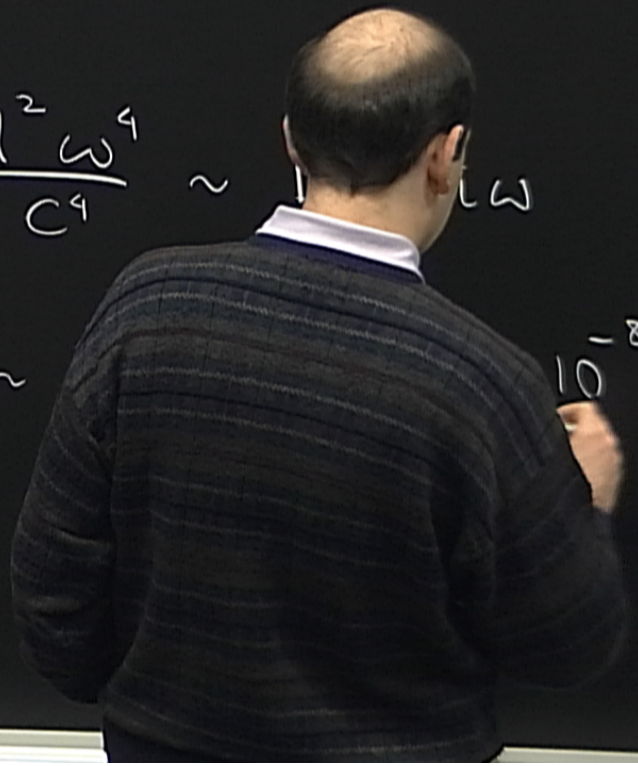
Decay Rate

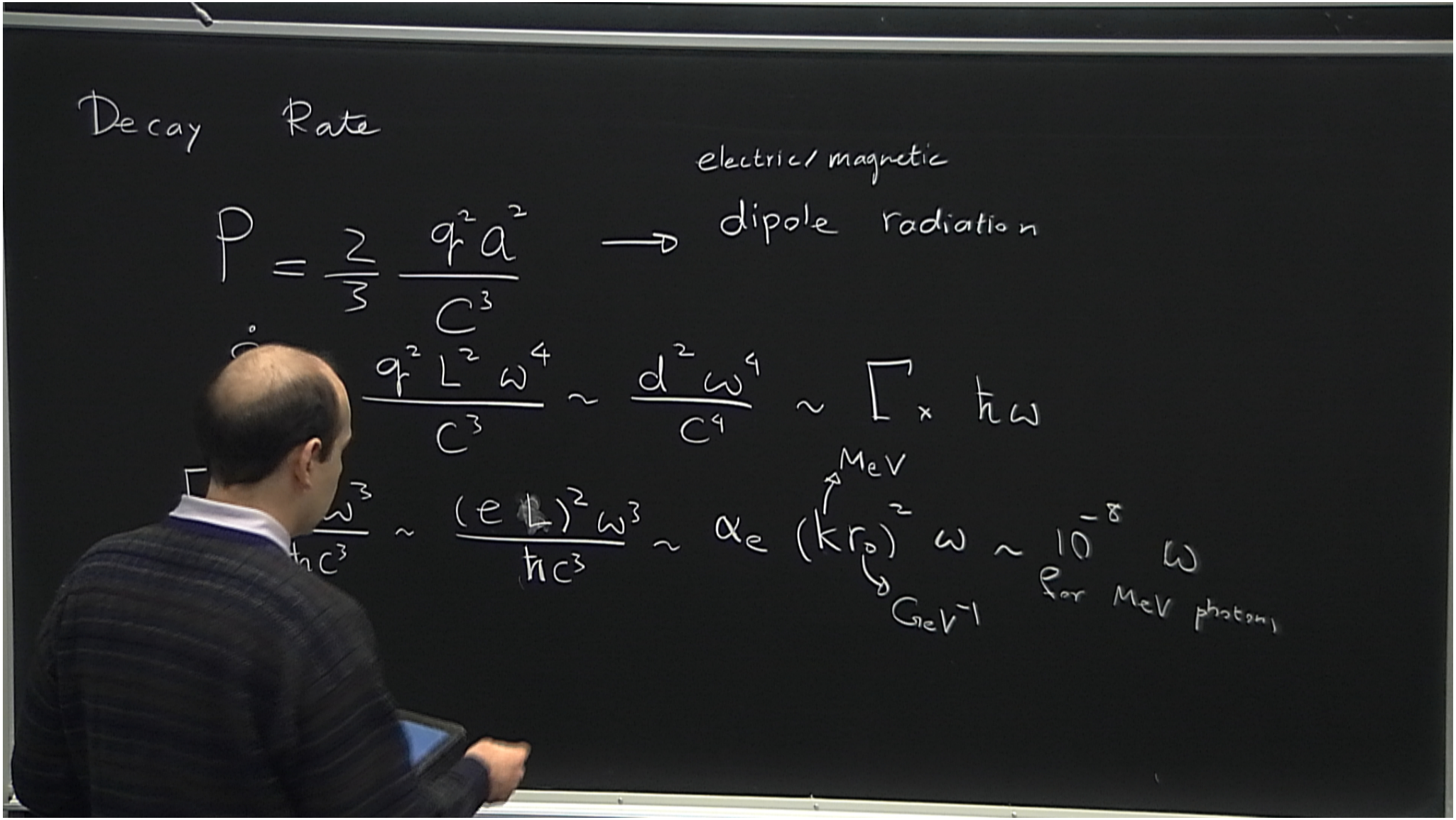
electric/magnetic

$$P = \frac{2}{3}\frac{q^2 a^2}{c^3} \longrightarrow \text{dipole radiation}$$

$$\dot{\mathcal{E}} \sim \frac{q^2 L^2 \omega^4}{c^3} \sim \frac{d^2 \omega^4}{c^4} \sim \; \omega$$

$$\Gamma \sim \frac{d^2\omega^3}{\hbar c^3} \sim \frac{(eL)^2\omega^3}{\hbar c^3} \sim \; 10^{-8} \; \omega$$




Decay Rate
electric/magnetic
$P = \frac{2}{3}\frac{q^2 a^2}{c^3}$ → dipole radiation
$\frac{q^2 L^2 \omega^4}{c^3} \sim \frac{d^2 \omega^4}{c^4} \sim \Gamma \times \hbar\omega$
$\frac{\omega^3}{\hbar c^3} \sim \frac{(eL)^2 \omega^3}{\hbar c^3} \sim \alpha_e (kr_0)^2 \omega \sim 10^{-8}\,\omega$
MeV
GeV^{-1}
for MeV photons

$$\rightarrow \Gamma \simeq \frac{d^2\omega^3}{\hbar c^3} \simeq \frac{(e r_0)^2 \omega^3}{\hbar c^3} \sim \alpha_e (k r_0)^2 \omega \quad (\omega \sim \text{GeV}^{-1})$$

$$\Gamma \sim \frac{\alpha_e \times E(\text{MeV}) \times \text{MeV}^3}{10^6\ \text{MeV}^2} \sim (10^{-8}\ \text{MeV})\ E^3(\text{MeV})$$

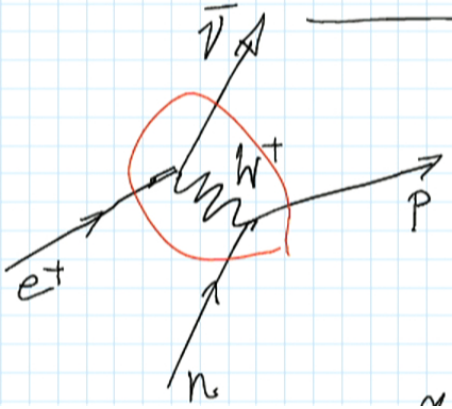
$$\sim 10^{13}\ s^{-1}\ E^3(\text{MeV})$$

$k = \frac{\omega}{c}$

$k r_0 \ll 1$

dipole app.

Weak Reactions



β-decay + ...

$$n \rightarrow p^+ + e^- + \bar{\nu}$$

$$n + e^+ \rightarrow p^+ + \bar{\nu}$$

$\vdots$

mediated by $W^\pm, Z$ boson

Weak Reactions



β-decay + ...

$n \to p^+ + e^- + \bar{\nu}$

$n + e^+ \to p^+ + \bar{\nu}$

$\vdots$

mediated by $W^\pm, Z$ boson

$m \sim 10^2$ GeV

$\alpha_W \simeq E^2 G_F$; $G_F \simeq 10^{-11}\ \text{MeV}^{-2}$

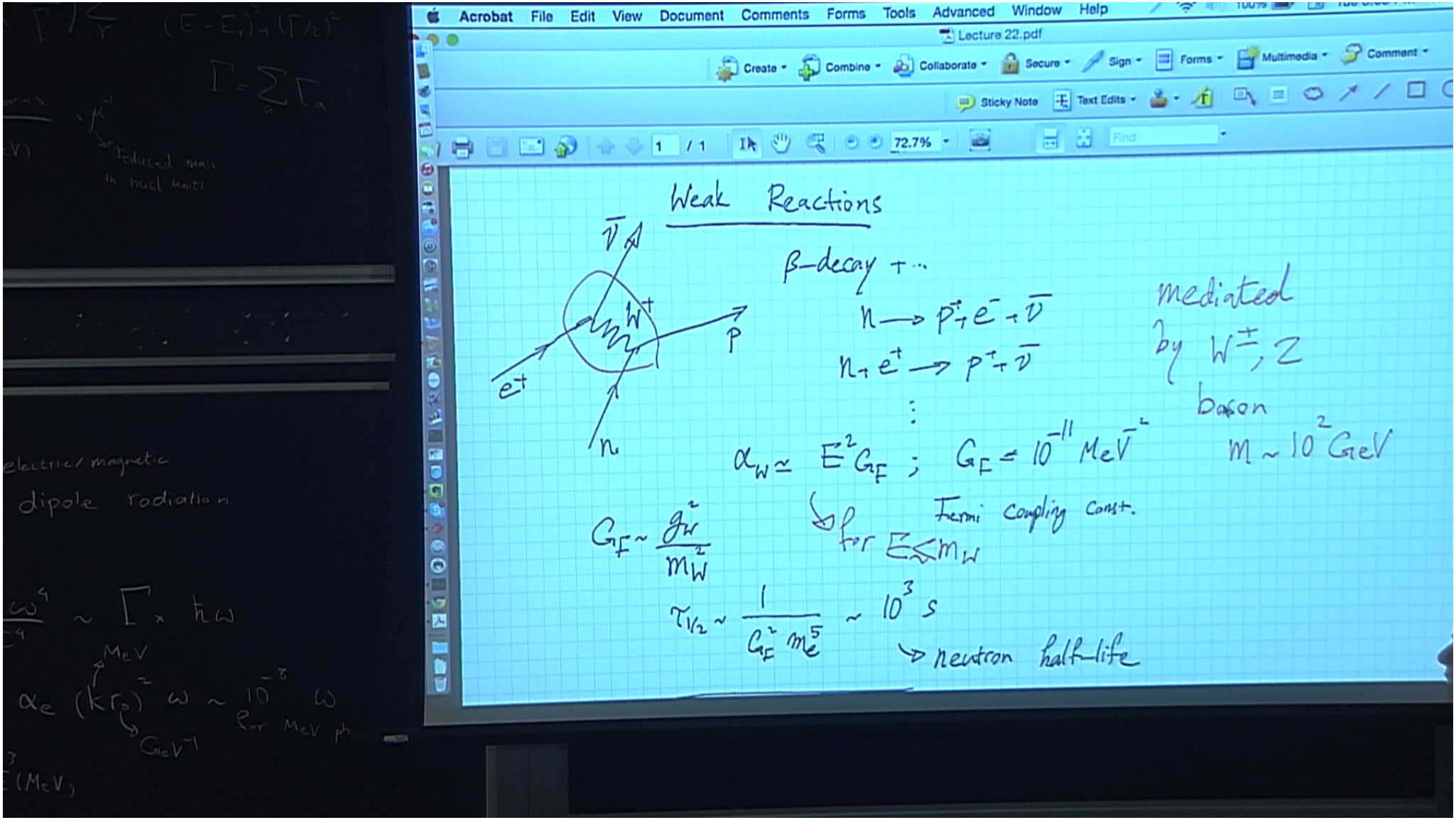
$G_F \sim \frac{g_W^2}{m_W^2}$

↳ for $E \lesssim m_W$

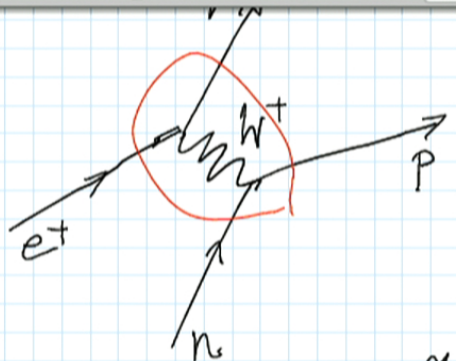
Fermi coupling const.

$\tau_{1/2} \sim \frac{1}{G_F^2 m_e^5} \sim 10^3\ s$

↳ neutron half-life


Acrobat File Edit View Document Comments Forms Tools Advanced Window Help
Lecture 22.pdf
Create Combine Collaborate Secure Sign Forms Multimedia Comment
Sticky Note Text Edits
Weak Reactions
β-decay + ...
n → p⁺ + e⁻ + ν̄
n + e⁺ → p⁺ + ν̄
mediated by W±, Z boson
m ~ 10² GeV
α_W ≃ E² G_F ; G_F ≃ 10⁻¹¹ MeV⁻²
Fermi coupling const.
for E ≪ m_W
G_F ~ g_W² / m_W²
τ_1/2 ~ 1 / (G_F² m_e⁵) ~ 10³ s
→ neutron half-life
e⁺
W⁺
p
n
ν̄

Acrobat File Edit View Document Comments Forms Tools Advanced Window Help 100% Tue 3:10 PM Niayesh Afshordi
Lecture 22.pdf
Create Combine Collaborate Secure Sign Forms Multimedia Comment
Sticky Note Text Edits Show
1 / 1 72.7% Find



β-decay + ...

$n \to p^+ + e^- + \bar{\nu}$

$n + e^+ \to p^+ + \bar{\nu}$

mediated by $W^\pm, Z$ boson

$m \sim 10^2$ GeV

$\alpha_N \simeq E^2 G_F$; $G_F \simeq 10^{-11}\ \text{MeV}^{-2}$

G_F Fermi coupling const.

$G_F \sim \frac{g_W^2}{m_W^2}$ for $E \lesssim m_W$

$\tau_{1/2} \sim \frac{1}{G_F^2 m_e^5} \sim 10^3$ s

→ neutron half-life

12 Basics of Nuclear Physics

most

Table 12.2. The carbon–nitrogen–oxygen cycles

CNO cycle for massive stars

Acrobat File Edit View Document Comments Forms Tools Advanced Window Help 100% Tue 3:14 PM Niayesh Afshordi

Lecture 22.pdf

Create Combine Collaborate Secure Sign Forms Multimedia Comment

Sticky Note Text Edits Show

1 / 1 72.7% Find

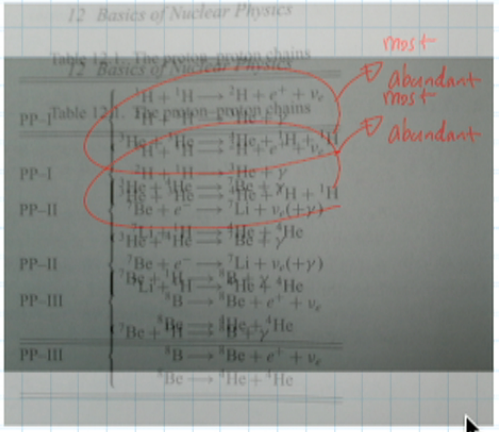
$\tau_{1/2} \sim \frac{G_F^2}{G_F^2} \frac{m_e^5}{m_e^5} \sim 10^{?}$ s

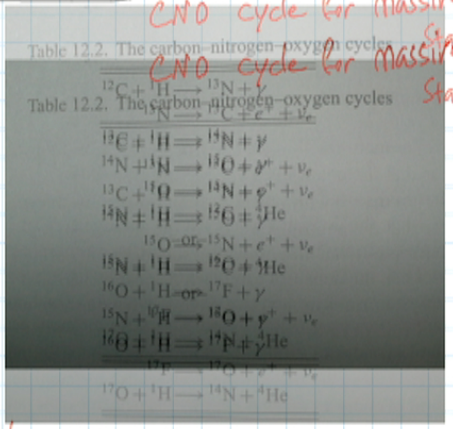
neutron half-life

neutron half-life

CNO cycle for massive stars

CNO cycle for massive stars





for Sun PP chain

for Sun PP chain

is 10 times more efficient

is 10 times more efficient

Helium Burning → White Dwarfs

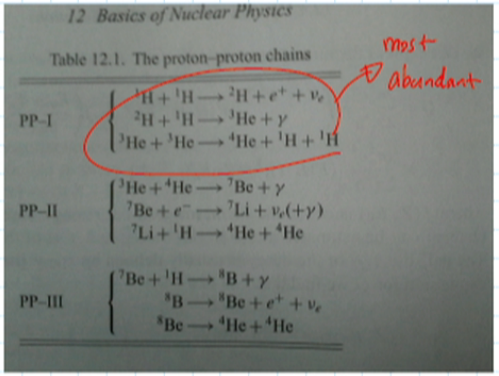
Helium Burning → White Dwarfs

Neutron Captures → Supernova

Neutron Captures → Supernova → elements heavier than iron

$t_{1/2}$ of ^{8}Be

→ neutron half-life



12 Basics of Nuclear Physics

Table 12.1. The proton–proton chains

most abundant

PP-I
$^1H + {}^1H \longrightarrow {}^2H + e^+ + \nu_e$
$^2H + {}^1H \longrightarrow {}^3He + \gamma$
$^3He + {}^3He \longrightarrow {}^4He + {}^1H + {}^1H$

PP-II
$^3He + {}^4He \longrightarrow {}^7Be + \gamma$
$^7Be + e^- \longrightarrow {}^7Li + \nu_e(+\gamma)$
$^7Li + {}^1H \longrightarrow {}^4He + {}^4He$

PP-III
$^7Be + {}^1H \longrightarrow {}^8B + \gamma$
$^8B \longrightarrow {}^8Be + e^+ + \nu_e$
$^8Be \longrightarrow {}^4He + {}^4He$

CNO cycle for massive stars

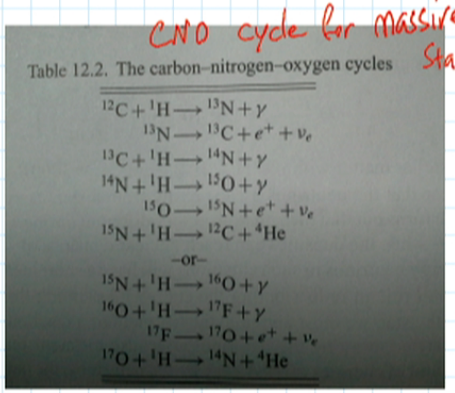


Table 12.2. The carbon–nitrogen–oxygen cycles

$^{12}C + {}^1H \longrightarrow {}^{13}N + \gamma$
$^{13}N \longrightarrow {}^{13}C + e^+ + \nu_e$
$^{13}C + {}^1H \longrightarrow {}^{14}N + \gamma$
$^{14}N + {}^1H \longrightarrow {}^{15}O + \gamma$
$^{15}O \longrightarrow {}^{15}N + e^+ + \nu_e$
$^{15}N + {}^1H \longrightarrow {}^{12}C + {}^4He$
–or–
$^{15}N + {}^1H \longrightarrow {}^{16}O + \gamma$
$^{16}O + {}^1H \longrightarrow {}^{17}F + \gamma$
$^{17}F \longrightarrow {}^{17}O + e^+ + \nu_e$
$^{17}O + {}^1H \longrightarrow {}^{14}N + {}^4He$

→ for sun PP chain is 10 times more efficient

Helium Burning → White Dwarfs

Neutron Captures → Supernova → elements heavier than iron

Acrobat File Edit View Document Comments Forms Tools Advanced Window Help 100% Tue 3:21 PM Niayesh Afshordi
Lecture 23.pdf
Create Combine Collaborate Secure Sign Forms Multimedia Comment
Sticky Note Text Edits
1 / 1 121% Find

High Energy Astrophysics

Historically refers to processes leading to Particle/Photon energies upward of ~ keV

Examples:

- Accretion onto relativistic compact objects: neutron stars & black holes
- Supernova Explosions & Gamma Ray Bursts

Examples:

- Accretion onto relativistic compact objects: neutron stars & black holes
- Supernova Explosions & Gamma Ray Bursts
- Conversion of large scale kinetic/gravitational energy into random energy: e.g.
  Galaxy Clusters, Stellar Coronae/Winds
  Fermi Acceleration → Cosmic Rays

Acrobat File Edit View Document Comments Forms Tools Advanced Window Help 99% Tue 3:24 PM Niayesh Afshordi
Lecture 23.pdf
Create Combine Collaborate Secure Sign Forms Multimedia Comment
Sticky Note Text Edits
1 / 1 121% Find

- Supernova Explosions & Gamma Ray Bursts

- Conversion of large scale kinetic/gravitational energy into random energy: e.g.

  Galaxy Clusters, Stellar Coronae/Winds

  Fermi Acceleration → Cosmic Rays

We will explore the basics of these processes the next couple of lectures

Fermi Acceleration → Cosmic Rays

We will explore the basics of these processes the next couple of lectures

Fermi Acceleration

First Imagine a static magnetized plasma.

Charged energetic particles