Physics 535 – Lecture 26
Physics of Lightning

Electron speed and effective temperature

3/28/16

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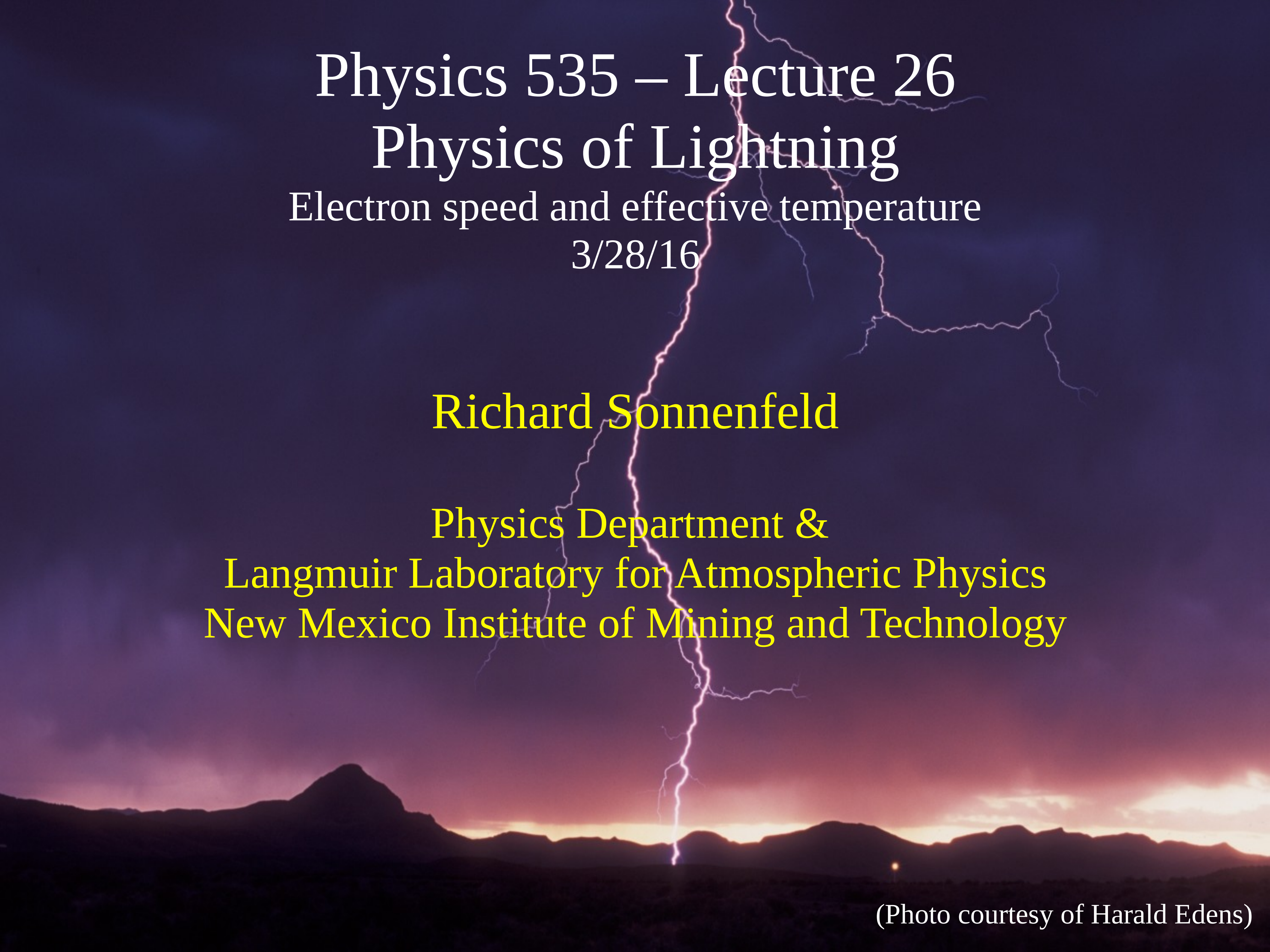


(Photo courtesy of Harald Edens)

Bazelyan 2.1

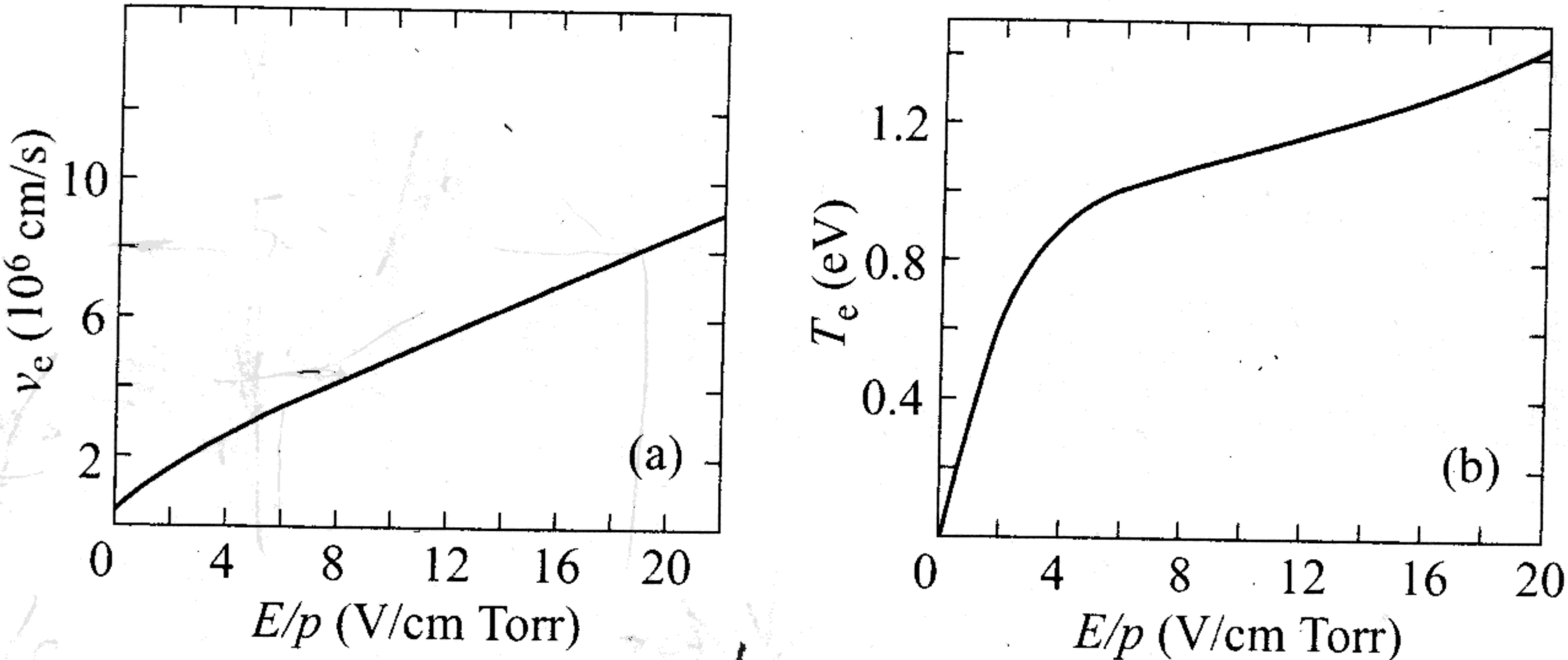
Mobility is a great concept – but what happens when the drift velocity is not negligible compared to the thermal velocity?

Electrons end up out of equilibrium. However, in a time given by

$$\tau = \frac{1}{\nu\delta} \qquad \delta = 2\frac{m_e}{m_{air}} \simeq 4\times10^{-5}$$

They transfer their energy back to the gas molecules. In the meantime, the have an "effective temperature", which is far higher than the gas temperature.

How can we "save" mobility theory to roughly calculate electron behavior?



$E = \frac{V}{cm \cdot Torr} \times p$

FIGURE 2.1

Electron drift velocity (a) [2.2] and temperature (b) [2.3] in air.

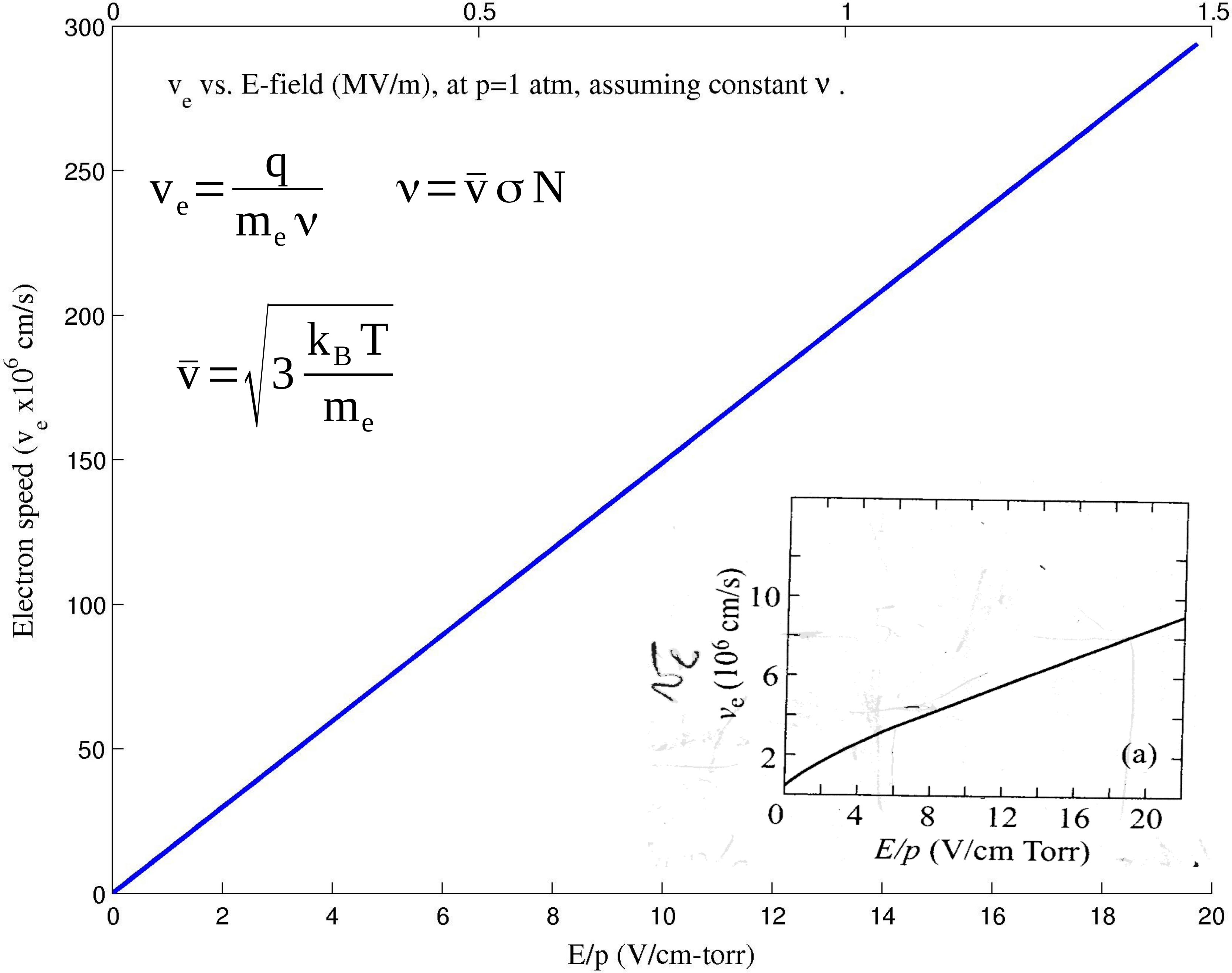


Figure2_1

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Define Effective Temperature

$$T_{eff} = T + \frac{m\, v_{drift}^2}{3\, k_B}$$

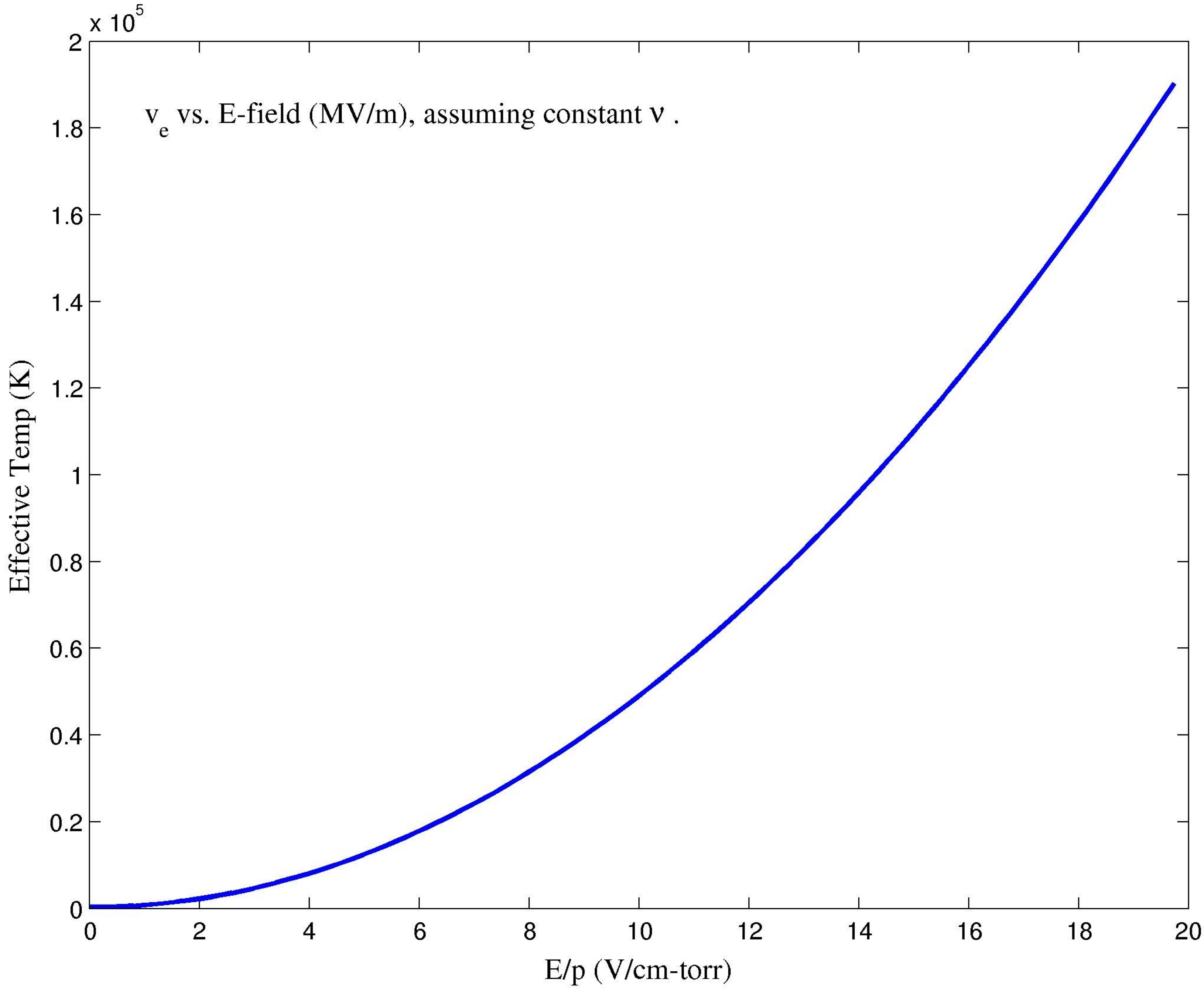
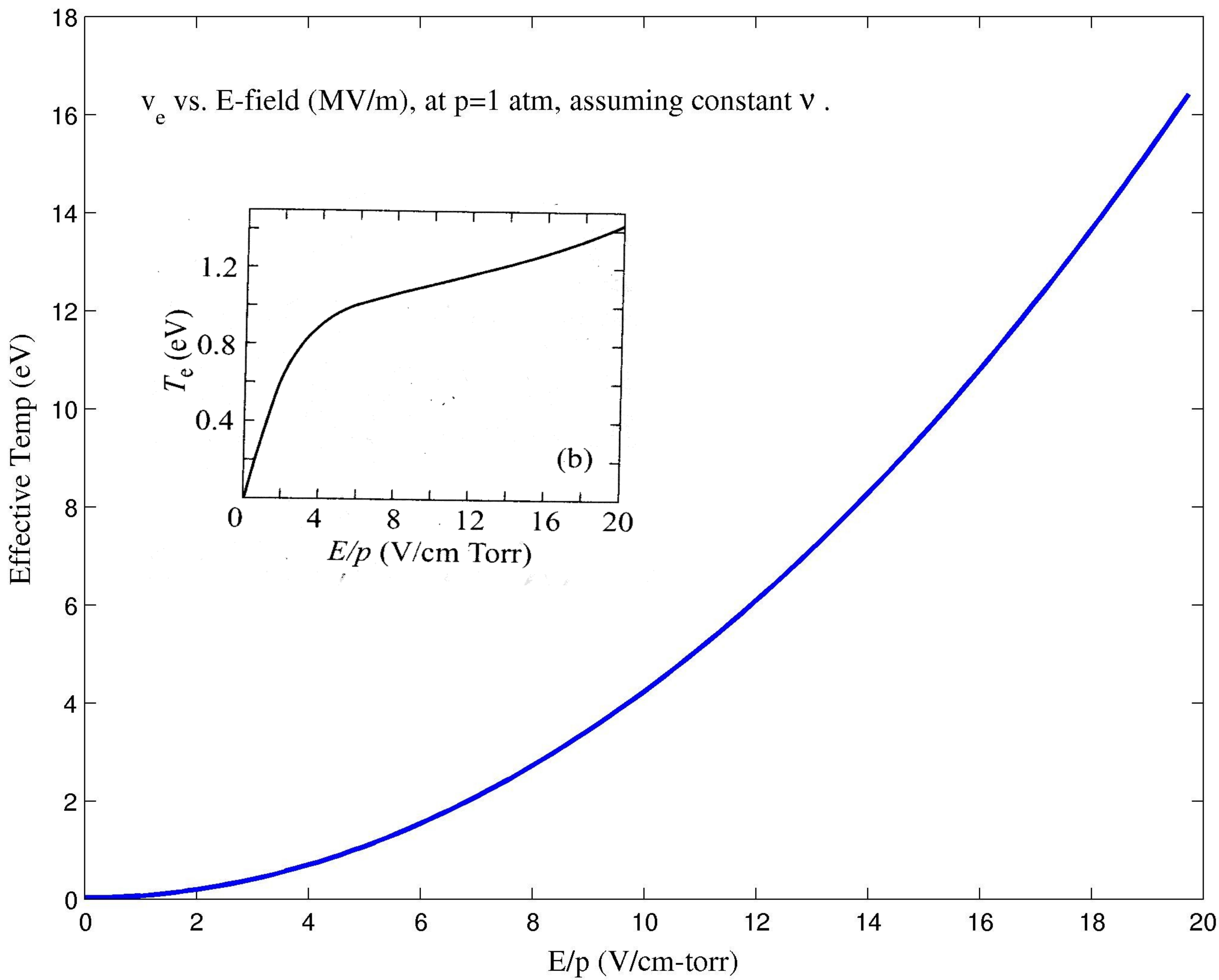
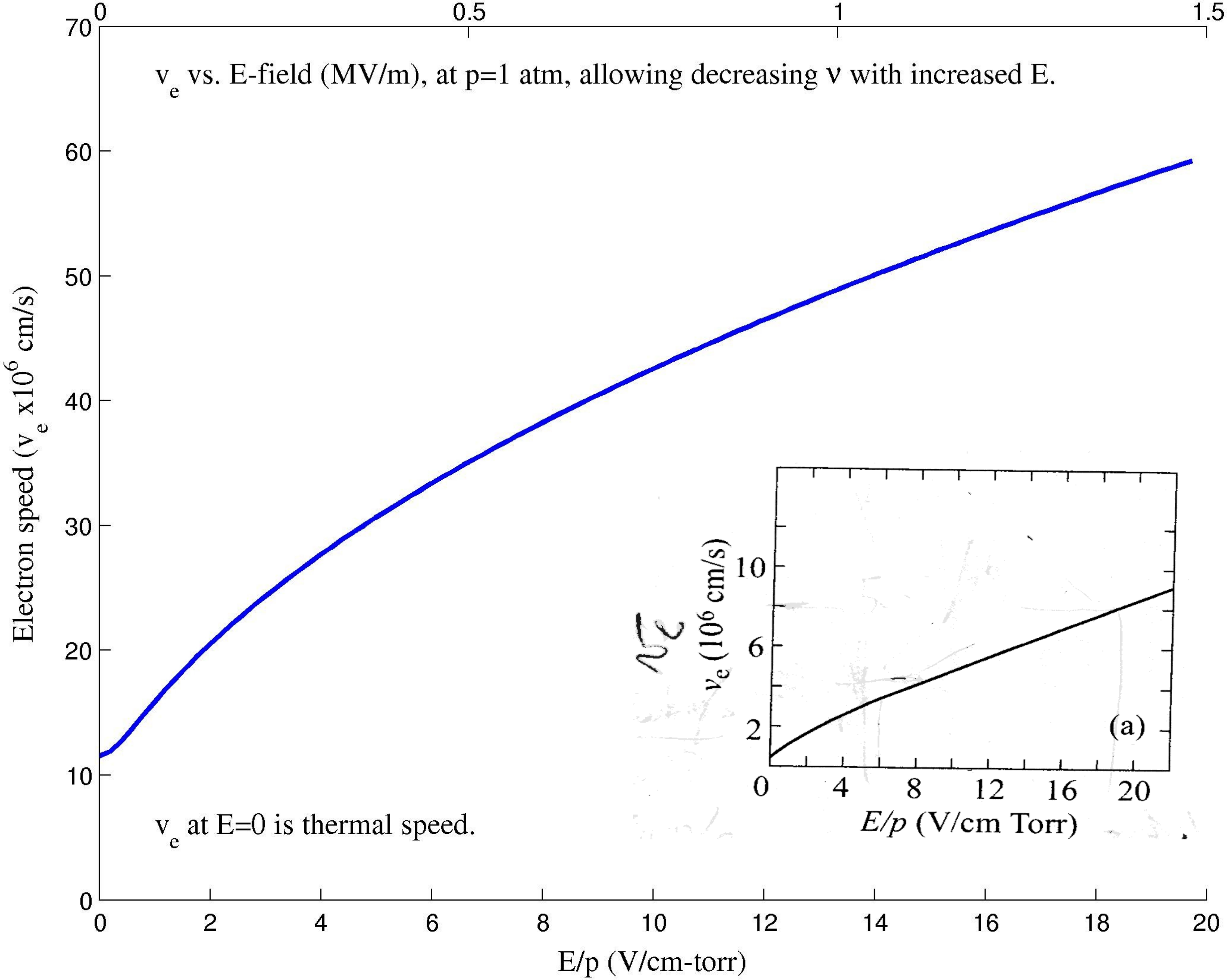


Figure2_1 R. Sonnenfeld -- As of: 29-Mar-2016


v_e vs. E-field (MV/m), at p=1 atm, assuming constant ν .
Effective Temp (eV)
E/p (V/cm-torr)
T_e (eV)
E/p (V/cm Torr)
(b)

Collisions get more frequent as electron moves faster

Assume "mean free path" is constant.



0
0.5
1
1.5
70
60
50
40
30
20
10
0
v_e vs. E-field (MV/m), at p=1 atm, allowing decreasing ν with increased E.
Electron speed (v_e x10^6 cm/s)
v_e at E=0 is thermal speed.
v_e (10^6 cm/s)
10
6
2
(a)
0
4
8
12
16
20
E/p (V/cm Torr)
0
2
4
6
8
10
12
14
16
18
20
E/p (V/cm-torr)

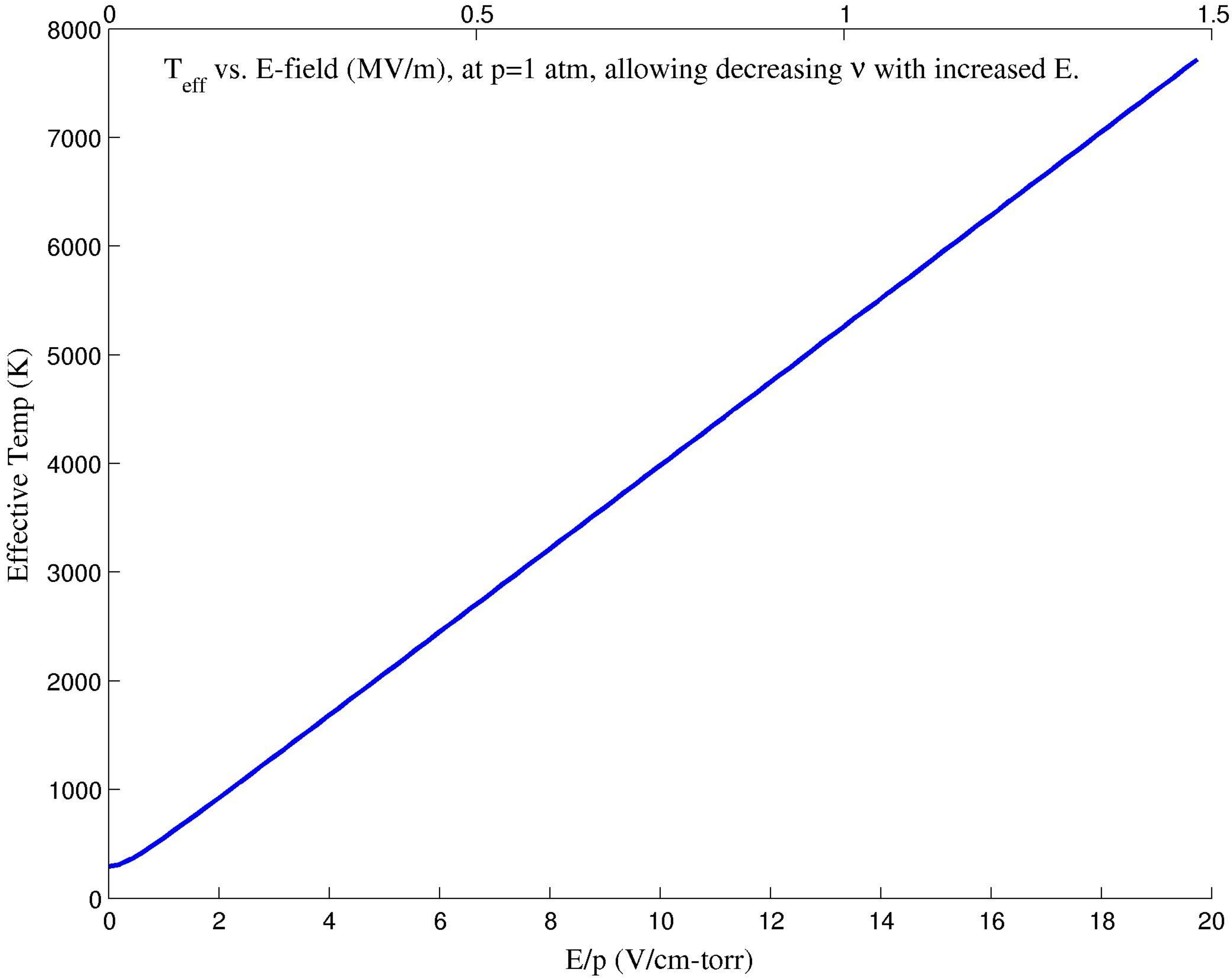


Figure2_1

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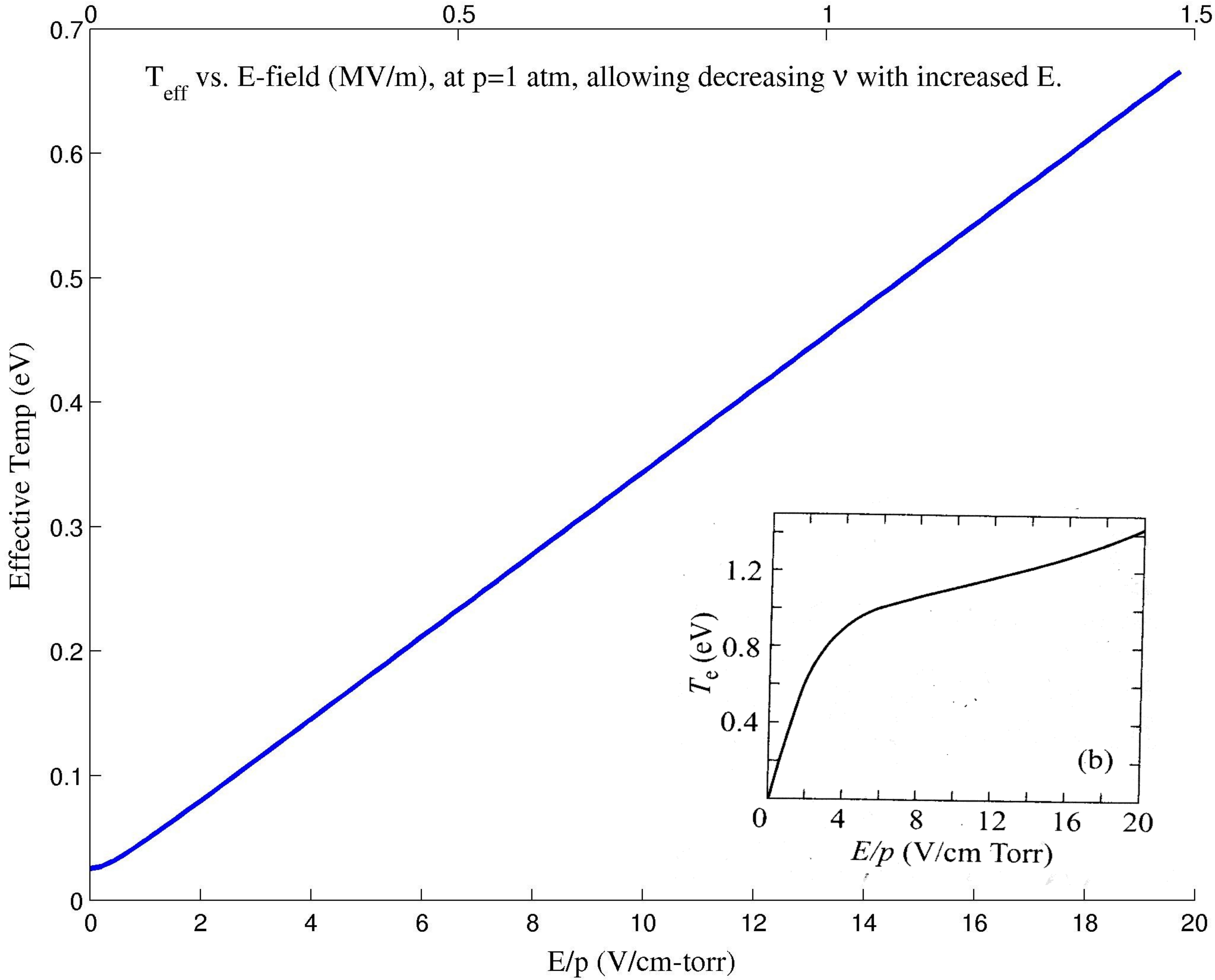

Figure2_1

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Deriving delta

The factor

$$\delta = 2\frac{m_e}{m_{air}} \simeq 4\times10^{-5}$$

Can be derived from classical momentum and energy conservation.

