We have thus shown that the formula (18) contains all known expressions for the stopping power as appropriate limiting cases. As far as the energy loss by a non-relativistic ion to quiescent Maxwellian plasma electrons is concerned, we thus believe that equation (18) constitutes the most general solution of the problem.

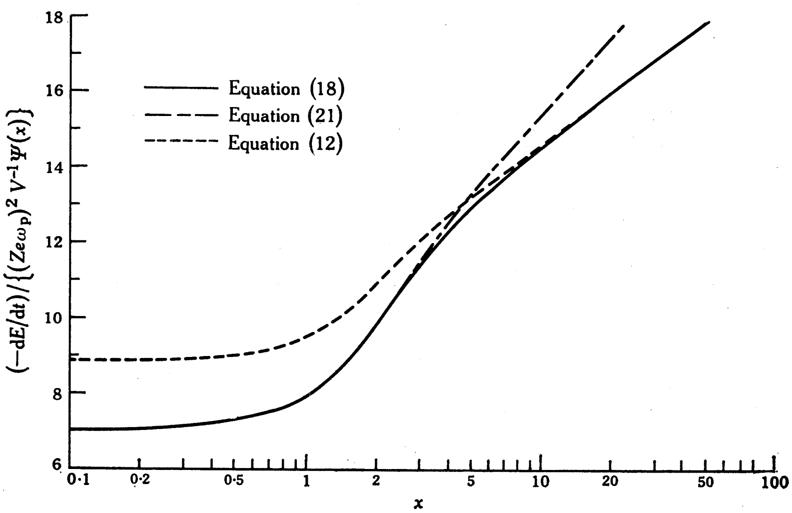

Fig. 1. Full quantum-theoretical energy loss rate dE/dt derived here (equation 18) compared with the classical (equation 21) and quantum (equation 12) limits. The graphs shown are for the parameter values $Z = 1$, $T = 2$ eV and $n = 10^{14}$ cm^{-3}.

4. Discussion

In the Introduction we argued that the energy loss of an ion to plasma electrons with $v \gg 1$ will be described by the quantum limit formula (12) for $v/x \ll 1$. As the ion slows down it will pass through the region $v/x \approx 1$, where the full quantum-theoretical equation (18) must be used to describe its behaviour, and finally it will settle down in the classical region with $x < 1$, where the classical equation (21) is applicable. These features are illustrated in Fig. 1 for $Z = 1$ (proton), $T = 2$ eV ($v = 2\cdot6$) and $n = 10^{14}$ cm^{-3}, parameters that are appropriate to the experiment by Burke and Post (1974). At $x \approx 1$, where the energy loss has been actually measured, the quantum effect is entirely negligible so that the analysis by Burke and Post of their experimental results is justified, except for their use of May's (1969) formula which is in error, as discussed in paper H.

The quantum effect in Caby-Eyraud's (1970) experiment for 5 keV protons at $T = 1\cdot5$ eV ($x = 1\cdot3$, $v = 3\cdot0$) is also negligible, the difference between equations (18) and (21) above being less than 1%.

Let us finally consider typical fusion plasmas. For $T > 10$ keV and fusion-produced alpha particles, the quantum limit (12) is practically exact since then $v < 0\cdot07$. We have evaluated the energy loss to electrons of an alpha particle, of energy $E \leqslant 3\cdot5$ MeV in a plasma with $n = 10^{14}$ cm^{-3} and $T = 20$ and 80 keV, using equation (12) and found excellent agreement with the results obtained by Sigmar and Joyce (1971). The Lenard–Balescu kinetic theory used by Sigmar and Joyce contains a divergence for large momentum transfers so that they had to introduce cutoffs in their calculation.

In view of this unsatisfactory feature of their calculations, it is somewhat surprising that such an excellent agreement has been found. This point will be discussed further in a forthcoming paper in which contributions of plasma ions will be included.

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