1. The relative permittivity of an ionised gas is given by

\[ \epsilon_r = \frac{c^2 k^2}{\omega^2} = 1 - \frac{\omega_0^2}{\omega^2} \]

where \( \omega_0 \) is the plasma oscillation frequency, and \( c \) is the speed of light.

What is the phase velocity for an electromagnetic wave of frequency \( \omega \)?

What is the group velocity for an electromagnetic wave of frequency \( \omega \)?

Are the phase and group velocities different from each other? Why?

2. A high-energy X-ray beam is focused on hydrogen gas and the wavelength of the ray at an angle of 50° is measured. Another X-ray of the same energy is focused on helium and the wavelength of the ray at an angle of 50° is measured. Assuming that the X-rays collide with valence electrons only, what should the relative shifts of wavelength be for the hydrogen and helium?

3. We focus an electron beam of energy 50 eV on a crystal of unknown interplanar distance. If we observe strong primary scattering of the electron beam at an angle of 60° to the perpendicular of the beam, what is the interplanar distance?