Light as an Electromagnetic Wave

Classical Zeeman effect or the triumph of Maxwell's equations! As pointed out in Section 3.1, Maxwell's equations may be used to predict the change in emission frequency when gas atoms are placed in a magnetic field. Consider the situation shown in Figure P3.1. Note that the application of a magnetic field perpendicular to the orbital plane of the electron induces an electric field, which changes the direction of the velocity vector. (a) Using

$$\oint \mathbf{E} \cdot d\mathbf{s} = -\frac{d\Phi_B}{dt}$$

show that the magnitude of the electric field is given by

$$E = \frac{r}{2} \frac{dB}{dt}$$

(b) Using $F\,dt = m\,dv$, calculate the change in speed, Δv, of the electron. Show that if r remains constant,

$$\Delta v = \frac{erB}{2m_e}$$

(c) Find the change in angular frequency, $\Delta\omega$, of the electron and calculate the numerical value of $\Delta\omega$ for B equal to 1 T. Note that this is also the change in frequency of the light emitted according to Maxwell's equations. Find the fractional change in frequency, $\Delta\omega/\omega$, for an ordinary emission line of 500 nm. (d) Actually, the original emission line at ω_0 is split into three components at $\omega_0 — \Delta\omega$, ω_0, and $\omega_0 + \Delta\omega$. The line at

$\omega_0 + \Delta\omega$ is produced by atoms with electrons rotating as shown in Figure P3.1, whereas the line at $\omega_0 - \Delta\omega$ is produced by atoms with electrons rotating in the opposite sense. The line at ω_0 is produced by atoms with electronic planes of rotation oriented parallel to **B**. Explain.

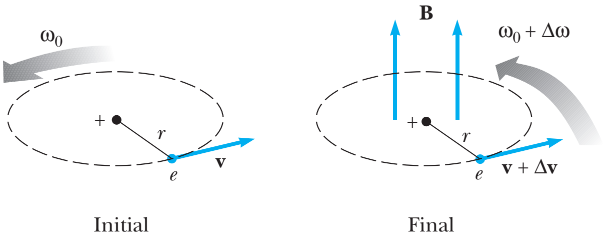

Figure P3.1