1. Turunkan dengan detail persamaan bloch sehingga mendapatkan hasil seperti pada pers. 14.43 – 14.44 pada buku teks

   Jawab:

$$\mathrm{E}(t) = E_0 \cos \omega t = \frac{E_0}{2}\left(e^{i\omega t} + e^{-i\omega t}\right)$$

$$\beta_{21}(t) = \rho_{21} e^{i\omega t}$$

$$\beta_{12}(t) = \beta_{21}^{*} = \rho_{12} e^{-i\omega t} = (\rho_{21})^{*} e^{-i\omega t}$$

   Maka persamaan

$$\dot{\rho}_{21} = i\frac{\mathrm{E}\mu_d}{\hbar}(\rho_{11} - \rho_{22}) - i\omega_{21}\rho_{21} - \frac{\rho_{21}}{T_2}$$

   Diubah kedalam bentuk β_{21} dengan mengalikan $e^{i\omega t}$

$$\left(\frac{d}{dt}\rho_{21}\right)e^{i\omega t} = i\frac{\mu_d}{2\hbar}\frac{E_0}{2}\left(e^{i\omega t} + e^{-i\omega t}\right) - i\omega_{21}\rho_{21}e^{i\omega t} - \frac{\rho_{21}}{T_2}e^{i\omega t}$$

$$\frac{d}{dt}\beta_{21} - i\omega\rho_{21}e^{i\omega t} = i\frac{\mu_d}{2\hbar}E_0\left(e^{2i\omega t} + 1\right)(\rho_{11} - \rho_{22}) - i\omega_{21}\beta_{21} - \frac{\beta_{21}}{T_2}$$

$$\frac{d}{dt}\beta_{21} = i\frac{\mu_d}{2\hbar}E_0(\rho_{11} - \rho_{22}) + i(\omega - \omega_{21})\beta_{21} - \frac{\beta_{21}}{T_2}$$

   Lalu hasil persamaan

$$\dot{\rho}_{11} - \dot{\rho}_{22} = 2i\frac{\mathrm{E}\mu_d}{\hbar}(\rho_{21} - \rho_{21}^{*}) - \frac{(\rho_{11} - \rho_{22}) - (\rho_{11} - \rho_{22})_0}{T_1}$$

   Jika dimasukkan E kedalan persamaan diatas maka

$$\dot{\rho}_{11} - \dot{\rho}_{22} = 2i\frac{\mu_d}{\hbar}\frac{E_0}{2}\left(e^{i\omega t} + e^{-i\omega t}\right)(\rho_{21} - \rho_{21}^{*}) - \frac{(\rho_{11} - \rho_{22}) - (\rho_{11} - \rho_{22})_0}{T_1}$$

$$= i\frac{\mu_d}{\hbar}E_0\left(\rho_{21}e^{i\omega t} - \rho_{21}^{*}e^{i\omega t} + \rho_{21}e^{-i\omega t} - \rho_{21}^{*}e^{-i\omega t}\right) - \frac{(\rho_{11} - \rho_{22}) - (\rho_{11} - \rho_{22})_0}{T_1}$$

$$= i\frac{\mu_d}{\hbar}E_0\left(\rho_{21}e^{i\omega t} - \beta_{21}^{*}e^{2i\omega t} + \beta_{21}e^{-2i\omega t} - \rho_{21}^{*}e^{-i\omega t}\right) - \frac{(\rho_{11} - \rho_{22}) - (\rho_{11} - \rho_{22})_0}{T_1}$$

$$= i\frac{\mu_d}{\hbar}E_0\left(\rho_{21}e^{i\omega t} - \rho_{21}^{*}e^{-i\omega t}\right) - \frac{(\rho_{11} - \rho_{22}) - (\rho_{11} - \rho_{22})_0}{T_1}$$

$$\dot{\rho}_{11} - \dot{\rho}_{22} = i\frac{\mu_d}{\hbar}E_0\left(\beta_{21} - \beta_{21}^{*}\right) - \frac{(\rho_{11} - \rho_{22}) - (\rho_{11} - \rho_{22})_0}{T_1}$$

2. Dapatkan solusi pers. Bloch untuk keadaan tunak [pers. (14.46)-(14.48)]

   Jawab:

   Tidak perubahan pada fractional population difference, $\rho_{11} - \rho_{22}$,

   maka $\frac{d(\rho_{11} - \rho_{22})}{dt} = 0$ dan $\frac{d\beta_{21}}{dt} = 0$

   kedua persamaan akan menjadi

$$0 = i\frac{\mu_d}{\hbar}E_0\left(\beta_{21} - \beta_{21}^{*}\right) - \frac{(\rho_{11} - \rho_{22}) - (\rho_{11} - \rho_{22})_0}{T_1} \qquad [\mathbf{1}]$$

$$0 = i\frac{\mu_d}{\hbar}E_0\left(\rho_{11} - \rho_{22}\right) + i(\omega - \omega_{21})\beta_{21} - \frac{\beta_{21}}{T_2}$$

$$i\frac{\mu_d}{\hbar}E_0\,(\rho_{11}-\rho_{22}) = \left(i(\omega_{21}-\omega)+\frac{1}{T_2}\right)\beta_{21}$$

$$\beta_{21} = \Omega(\rho_{11}-\rho_{@2})\frac{1}{\left(\omega_{21}-\omega-\frac{i}{T_2}\right)}$$

Dengan $\Omega = \frac{\mu_d}{2\hbar}E_0$, dan konjugatnya $\beta_{21} = \Omega(\rho_{11}-\rho_{22})\frac{1}{\left(\omega_{21}-\omega-\frac{i}{T_2}\right)}$

[1] dapat diubah menjadi

$$i2\Omega(\beta_{21}-\beta_{21}^*) = \frac{(\rho_{11}-\rho_{22})-(\rho_{11}-\rho_{22})_0}{T_1}$$

Subtitusi nilai β

$$i2\Omega(\rho_{11}-\rho_{22})\left(\frac{1}{\left(\omega_{21}-\omega-\frac{i}{T_2}\right)}-\frac{1}{\left(\omega_{21}-\omega+\frac{i}{T_2}\right)}\right) = \frac{(\rho_{11}-\rho_{22})-(\rho_{11}-\rho_{22})_0}{T_1}$$

$$(\rho_{11}-\rho_{22})\left(-\frac{1}{\left(\omega_{21}-\omega-\frac{i}{T_2}\right)}+\frac{1}{\left(\omega_{21}-\omega+\frac{i}{T_2}\right)}+\frac{1}{i2\Omega^2T_1}\right) = \frac{(\rho_{11}-\rho_{22})_0}{i2\Omega^2T_1}$$

$$(\rho_{11}-\rho_{22})\left(\frac{T_2}{(T_2(\omega_{21}-\omega)+i)}-\frac{T_2}{(T_2(\omega_{21}-\omega)-i)}+\frac{1}{i2\Omega^2T_1}\right) = \frac{(\rho_{11}-\rho_{22})_0}{i2\Omega^2T_1}$$

$$\ldots+\frac{1}{i2\Omega^2T_1} = \frac{T_2\big((T_2(\omega_{21}-\omega)-i)-(T_2(\omega_{21}-\omega)+i)\big)}{(T_2(\omega_{21}-\omega)+i)(T_2(\omega_{21}-\omega)-i)}+\frac{1}{i2\Omega^2T_1}$$

$$= \frac{T_2(-2i)}{(T_2)^2(\omega_{21}-\omega)+1}+\frac{1}{i2\Omega^2T_1}$$

$$= \frac{T_2(-2i)i2\Omega^2T_1+(T_2)^2(\omega_{21}-\omega)^2+1}{((T_2)^2(\omega_{21}-\omega)^2+1)i2\Omega^2T_1}$$

$$\ldots+\frac{1}{i2\Omega^2T_1} = \frac{1+(\omega_{21}-\omega)^2T_2^2+4\Omega^2T_2T_1}{((T_2)^2(\omega_{21}-\omega)^2+1)i2\Omega^2T_1}$$

$$(\rho_{11}-\rho_{22})\left(\frac{1+(\omega_{21}-\omega)^2T_2^2+4\Omega^2T_2T_1}{((T_2)^2(\omega_{21}-\omega)^2+1)i2\Omega^2T_1}\right) = \frac{(\rho_{11}-\rho_{22})_0}{i2\Omega^2T_1}$$

$$(\rho_{11}-\rho_{22}) = (\rho_{11}-\rho_{22})_0\frac{1+(\omega_{21}-\omega)^2T_2^2}{1+(\omega_{21}-\omega)^2T_2^2+4\Omega^2T_2T_1}$$

Setelah mendapatkan $\rho_{11}-\rho_{22}$, lalu dapat mencari nilai β_{21}

$$\beta_{21} = \Omega(\rho_{11}-\rho_{22})\frac{1+(\omega_{21}-\omega)^2T_2^2}{1+(\omega_{21}-\omega)^2T_2^2+4\Omega^2T_2T_1}\frac{1}{\left(\omega_{21}-\omega-\frac{i}{T_2}\right)}$$

$$\beta_{21} = \Omega(\rho_{11}-\rho_{22})\frac{1+(\omega_{21}-\omega)^2T_2^2}{1+(\omega_{21}-\omega)^2T_2^2+4\Omega^2T_2T_1}\frac{T_2}{(T_2(\omega_{21}-\omega)-i)}$$

$$\beta_{21} = \Omega(\rho_{11} - \rho_{22}) \frac{(T_2(\omega_{21} - \omega) + i)(T_2(\omega_{21} - \omega) - i)}{1 + (\omega_{21} - \omega)^2 T_2^2 + 4\Omega^2 T_2 T_1} \frac{T_2}{(T_2(\omega_{21} - \omega) - i)}$$

$$\beta_{21} = \Omega(\rho_{11} - \rho_{22}) \frac{(T_2^2(\omega_{21} - \omega) + iT_2)}{1 + (\omega_{21} - \omega)^2 T_2^2 + 4\Omega^2 T_2 T_1}$$

Maka nilai real adan imajinernya menajdi

$$\text{real}(\beta_{21}) = \frac{\Omega(\rho_{11} - \rho_{22})_0 T_2^2(\omega_{21} - \omega)}{1 + (\omega_{21} - \omega)^2 T_2^2 + 4\Omega^2 T_2 T_1}$$

$$\text{Im}(\beta_{21}) = \frac{\Omega(\rho_{11} - \rho_{22})_0 T_2}{1 + (\omega_{21} - \omega)^2 T_2^2 + 4\Omega^2 T_2 T_1}$$

3. Temukan relasi yang sesuai antara “suseptibilitas kompleks” dan “fungsi dielektrik”

   Jawab:

   Diketahui Polarisasi P $\mathrm{P} = \epsilon_0 \chi \mathrm{E}$

   Displacement D

$$\mathrm{D} = \epsilon_0 \mathrm{E} + \mathrm{P} = \epsilon \mathrm{E}$$
$$\epsilon_0 \mathrm{E} + \epsilon_0 \chi \mathrm{E} = \epsilon \mathrm{E}$$
$$\frac{\epsilon}{\epsilon_0} = 1 + \chi$$
$$\epsilon_r = 1 + \chi$$

   χ adalah bilangan kompleks dan ϵ_r adalah permitivias relatif atau complex frequancy dependent dielectric constant. Maka untuk relasi yang sesuai antara “suseptibilitas kompleks” dan “fungsi dielektrik” didapat $\epsilon' + i\epsilon'' = (1 + \chi') + i\chi''$