or as this (find out which),

$$\delta_\nu = \tag{4.26}$$

$$\Big(\frac{3}{10}a - \frac{1}{5}K\Big)\delta_{cdm,0}a + \cos\left(\frac{2\sqrt{K}}{\sqrt{a}}\right)\Big(c_1 - \frac{4}{5}\delta_{cdm,0}K^2\mathrm{Ci}\left(\frac{2\sqrt{K}}{\sqrt{a}}\right)\Big) \tag{4.27}$$

$$-2\sin\left(\frac{2\sqrt{K}}{\sqrt{a}}\right)\Big(c_2 + \frac{4}{5}\delta_{cdm,0}K^2\mathrm{Si}\left(\frac{2\sqrt{K}}{\sqrt{a}}\right)\Big) \tag{4.28}$$

$$\delta_\nu \simeq c_1\cos\left(\frac{2\sqrt{K}}{\sqrt{a}}\right) - \left(\frac{2}{5}\delta_{cdm,0}K^2\pi + c_2\right)\sin\left(\frac{2\sqrt{K}}{\sqrt{a}}\right) \tag{4.29}$$

$$\delta_\nu \simeq c_1\cos\left(\frac{2\sqrt{K}}{\sqrt{a}}\right) - \left(\frac{2}{5}\delta_{0,2}K^2\pi + c_2\right)\sin\left(\frac{2\sqrt{K}}{\sqrt{a}}\right) \tag{4.30}$$

Ansatz:For early time

$$\delta_\nu \simeq A\cos\left(\frac{2\sqrt{K}}{\sqrt{a}} + \Phi\right) \tag{4.31}$$

$$= A\cos\left(\frac{2\sqrt{K}}{\sqrt{a}}\right)\cos\left(\Phi\right) - A\sin\left(\frac{2\sqrt{K}}{\sqrt{a}}\right)\sin\left(\Phi\right) \tag{4.32}$$

$$\Phi = 0 \tag{4.33}$$

$$c_1 = A\cos\left(\Phi\right) \quad c_2 = A\sin\left(\Phi\right) - \frac{2}{5}\delta_{cdm,0}K^2\pi \tag{4.34}$$

$$c_1 = A \quad c_2 = -\frac{2}{5}\delta_{cdm,0}K^2\pi \tag{4.35}$$

$$\dot{\delta_\nu} = \frac{2\sqrt{K}}{2\sqrt{a^3}}\sin\left(\frac{2\sqrt{K}}{\sqrt{a}}\right) = \sqrt{\frac{K}{a^3}}\sin\left(\frac{2\sqrt{K}}{\sqrt{a}}\right) \tag{4.36}$$

$$A = \sqrt{\delta_\nu^2 + \left(\frac{\dot{\delta_\nu}}{\frac{\sqrt{K}}{\sqrt{a^3}}}\right)^2} = \sqrt{\delta_\nu^2 + \left(\frac{\dot{\delta_\nu}\sqrt{a^3}}{\sqrt{K}}\right)^2}\Bigg|_{a=a_0} \tag{4.37}$$

4.2 second order

Dette er nok forkert. (det er forresten i conformal time, tror jeg).

$$\ddot{\delta}^{(2)} + \mathcal{H}\dot{\delta}^{(2)} + 2\mathcal{H}\theta^{(2)} + 2k^2c_s(a)^2\Big(\delta^{(1)}\delta^{(1)} + \frac{1}{2}\delta^{(2)} + (\partial_j\delta^{(1)})\partial_j\nabla^{-2}\delta^{(1)}\Big) \tag{4.38}$$

$$= 2\theta^{(1)}\theta^{(1)} + 2(\partial_i\partial_j\nabla^{-2}\theta^{(1)})^2 + 4(\partial_j\nabla^{-2}\theta^{(1)})(\partial_j\theta^{(1)}) \tag{4.39}$$

$$+ 3H_0^2\frac{\Omega_m}{a}\Big(\delta^{(1)}\delta^{(1)}_{cdm} + \frac{1}{2}\delta^{(2)}_{cdm} + (\partial_j\delta^{(1)})(\partial_j\nabla^{-2}\delta^{(1)}_{cdm})\Big) \tag{4.40}$$

nyt forsøg

først har vi vores startligninger

$$\dot{\delta}^{(1)} = -\theta^{(1)} \quad \dot{\theta}^{(1)} = -\mathcal{H}\theta^{(1)} - \frac{3}{2}\frac{H_0^2\Omega_M}{a}\delta_M^{(1)} - c_s^2\nabla^2\delta^{(1)} \tag{4.41}$$

$$\dot{\delta}_\nu^{(2)} = -2\partial_j\nabla^{-2}\theta^{(1)}\partial_j\delta^{(1)} - 2\delta^{(1)}\theta^{(1)} - \theta^{(2)} \tag{4.42}$$

$$\dot{\theta}^{(2)} = -\mathcal{H}\theta^{(2)} - 2\Big(\partial_i\partial_j\nabla^{-2}\theta^{(1)}\partial_i\partial_j\theta^{(1)}\Big) - 2\partial_j\nabla^{-2}\theta^{(1)}\partial_j\theta^{(1)} \tag{4.43}$$

$$-\frac{3}{2}\frac{H_0^2\Omega_M}{a}\delta_M^{(2)} - c_s^2\nabla^2\delta^{(2)} \tag{4.44}$$

$$\ddot{\delta}^{(2)} = -2\partial_j\nabla^{-2}\theta^{(1)}\partial_j\delta^{(1)} - 2\partial_j\nabla^{-2}\dot{\theta}^{(1)}\partial_j\dot{\delta}^{(1)} - 2\dot{\delta}^{(1)}\theta^{(1)} - 2\delta^{(1)}\dot{\theta}^{(1)} - \dot{\theta}^{(2)} \tag{4.45}$$

$$\ddot{\delta}^{(2)} = -2\partial_j\nabla^{-2}\theta^{(1)}\partial_j\delta^{(1)} - 2\partial_j\nabla^{-2}\dot{\theta}^{(1)}\partial_j\dot{\delta}^{(1)} - 2\dot{\delta}^{(1)}\theta^{(1)} - 2\delta^{(1)}\dot{\theta}^{(1)} \tag{4.46}$$

$$+\frac{3}{2}\frac{H_0^2\Omega_M}{a}\delta_M^{(2)} + c_s^2\nabla^2\delta^{(2)} + 2\Big(\partial_i\partial_j\nabla^{-2}\theta^{(1)}\partial_i\partial_j\theta^{(1)}\Big) + 2\partial_j\nabla^{-2}\theta^{(1)}\partial_j\theta^{(1)} + \mathcal{H}\theta^{(2)} \tag{4.47}$$

$$\ddot{\delta}^{(2)} = -2\partial_j\nabla^{-2}\theta^{(1)}\partial_j\delta^{(1)} - 2\partial_j\nabla^{-2}\dot{\theta}^{(1)}\partial_j\dot{\delta}^{(1)} - 2\dot{\delta}^{(1)}\theta^{(1)} - 2\delta^{(1)}\dot{\theta}^{(1)} \tag{4.48}$$

$$+\frac{3}{2}\frac{H_0^2\Omega_M}{a}\delta_M^{(2)} + c_s^2\nabla^2\delta^{(2)} + 2\Big(\partial_i\partial_j\nabla^{-2}\theta^{(1)}\partial_i\partial_j\theta^{(1)}\Big) + 2\partial_j\nabla^{-2}\theta^{(1)}\partial_j\theta^{(1)} \tag{4.49}$$

$$+\mathcal{H}(-2\partial_j\nabla^{-2}\theta^{(1)}\partial_j\delta^{(1)} - 2\delta^{(1)}\theta^{(1)} - \dot{\delta}_\nu^{(2)}) \tag{4.50}$$

$$\tag{4.51}$$

$$\ddot{\delta}^{(2)} = 2\partial_j\nabla^{-2}\delta^{(1)}\partial_j\delta^{(1)} + 2\partial_j\nabla^{-2}(\mathcal{H}\delta^{(1)} - \frac{3}{2}\frac{H_0^2\Omega_M}{a}\delta_M^{(1)} - c_s^2\nabla^2\delta^{(1)})^{(1)}\partial_j\dot{\delta}^{(1)} \tag{4.52}$$

$$+2\dot{\delta}^{(1)}\dot{\delta}^{(1)} - 2\delta^{(1)}(\mathcal{H}\delta^{(1)} - \frac{3}{2}\frac{H_0^2\Omega_M}{a}\delta_M^{(1)} - c_s^2\nabla^2\delta^{(1)}) \tag{4.53}$$

$$+\frac{3}{2}\frac{H_0^2\Omega_M}{a}\delta_M^{(2)} + c_s^2\nabla^2\delta^{(2)} + 2\Big(\partial_i\partial_j\nabla^{-2}\dot{\delta}^{(1)}\partial_i\partial_j\dot{\delta}^{(1)}\Big) + 2\partial_j\nabla^{-2}\dot{\delta}^{(1)}\partial_j\dot{\delta}^{(1)} \tag{4.54}$$

$$+\mathcal{H}(2\partial_j\nabla^{-2}\dot{\delta}^{(1)}\partial_j\delta^{(1)} + 2\delta^{(1)}\dot{\delta}^{(1)} - \dot{\delta}^{(2)}) \tag{4.55}$$

bedre opskrivning

$$\ddot{\delta}^{(2)} + \mathcal{H}\dot{\delta}^{(2)} = \frac{3}{2}\frac{H_0^2}{a}\Big(2\partial_j\nabla^{-2}\delta_M^{(1)}\partial_j\delta^{(1)} + 2\delta^{(1)}\delta_M^{(1)} + \delta_M^{(2)}\Big) \tag{4.56}$$

$$+c_s^2\Big(2\partial_j\delta^{(1)}\partial_j\delta^{(1)} + 2\delta^{(1)}\nabla^2\delta^{(1)} + \nabla^2\delta^{(2)}\Big) \tag{4.57}$$

$$4\partial_j\nabla^{-2}\dot{\delta}^{(1)}\partial_j\dot{\delta}^{(1)} + 2\dot{\delta}^{(1)}\dot{\delta}^{(1)} + 2\partial_i\partial_j\nabla^{-2}\dot{\delta}^{(1)}\partial_i\partial_j\nabla^{-2}\dot{\delta}^{(1)} \tag{4.58}$$

$$\ddot{\delta}^{(2)} + \mathcal{H}\dot{\delta}^{(2)} = \frac{3}{2}\frac{H_0^2}{a}\Big(2\partial_j\nabla^{-2}\delta_M^{(1)}\partial_j\delta^{(1)} + 2\delta^{(1)}\delta_M^{(1)} + \delta_M^{(2)}\Big) \tag{4.59}$$

$$+4\partial_j\nabla^{-2}\dot{\delta}^{(1)}\partial_j\dot{\delta}^{(1)} + 2\dot{\delta}^{(1)}\dot{\delta}^{(1)} + 2\partial_i\partial_j\nabla^{-2}\dot{\delta}^{(1)}\partial_i\partial_j\nabla^{-2}\dot{\delta}^{(1)} \tag{4.60}$$

$$a = \frac{1}{4}H_0^2\tau^2 \quad \delta^{(1)} = D\tilde{\delta} \quad \delta_M = a\tilde{\delta}_M \quad \mathcal{H} = H_0/\sqrt{a} = \frac{2}{\tau} \tag{4.61}$$

$$\tag{4.62}$$

Vi indsætter og ser hvad der sker,

$$\ddot{\delta}^{(2)} + \frac{2}{\tau}\dot{\delta}^{(2)} - c_s^2\nabla^2\delta^{(2)} - \frac{6}{\tau^2}\delta_M^{(2)} = \frac{6}{\tau^2}\Big(2\partial_j\nabla^{-2}a\tilde{\delta}_M^{(1)}\partial_j D\tilde{\delta}^{(1)} + 2D\tilde{\delta}^{(1)}a\tilde{\delta}_M^{(1)}\Big) \tag{4.63}$$

$$+4\dot{D}^2\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\partial_j\tilde{\delta}^{(1)} + 2\dot{D}^2\tilde{\delta}^{(1)}\tilde{\delta}^{(1)} + 2\dot{D}^2\partial_i\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\partial_i\partial_j\nabla^{-2}\tilde{\delta}^{(1)} \tag{4.64}$$

$$+c_s^2\Big(2\partial_j D\tilde{\delta}^{(1)}\partial_j D\tilde{\delta}^{(1)} + 2D\tilde{\delta}^{(1)}\nabla^2 D\tilde{\delta}^{(1)}\Big) \tag{4.65}$$

reducere

$$\ddot{\delta}^{(2)} + \frac{2}{\tau}\dot{\delta}^{(2)} - c_s^2\nabla^2\delta^{(2)} - \frac{6}{\tau^2}\delta_M^{(2)} = aD\frac{6}{\tau^2}\Big(2\partial_j\nabla^{-2}\tilde{\delta}_M^{(1)}\partial_j\tilde{\delta}^{(1)} + 2\tilde{\delta}^{(1)}\tilde{\delta}_M^{(1)}\Big) \tag{4.66}$$

$$+4\dot{D}^2\Big(\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\partial_j\tilde{\delta}^{(1)} + 2\tilde{\delta}^{(1)}\tilde{\delta}^{(1)} + 2\partial_i\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\partial_i\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\Big) \tag{4.67}$$

$$+c_s^2D^2\Big(2\partial_j\tilde{\delta}^{(1)}\partial_j\tilde{\delta}^{(1)} + 2\tilde{\delta}^{(1)}\nabla^2\tilde{\delta}^{(1)}\Big) \tag{4.68}$$

$$\ddot{\delta}^{(2)} + \frac{2}{\tau}\dot{\delta}^{(2)} - c_s^2\nabla^2\delta^{(2)} - \frac{6}{\tau^2}\delta_M^{(2)} = D\frac{3}{2}H_0^2\Big(2\partial_j\nabla^{-2}\tilde{\delta}_M^{(1)}\partial_j\tilde{\delta}^{(1)} + 2\tilde{\delta}^{(1)}\tilde{\delta}_M^{(1)}\Big) \tag{4.69}$$

$$+4\dot{D}^2\Big(\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\partial_j\tilde{\delta}^{(1)} + 2\tilde{\delta}^{(1)}\tilde{\delta}^{(1)} + 2\partial_i\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\partial_i\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\Big) \tag{4.70}$$

$$+c_s^2D^2\Big(2\partial_j\tilde{\delta}^{(1)}\partial_j\tilde{\delta}^{(1)} + 2\tilde{\delta}^{(1)}\nabla^2\tilde{\delta}^{(1)}\Big) \tag{4.71}$$

Citat fra Steen “anden ordens termer for nuetrino bliver først relevant når neutrinoerne er stoppet med at oscillere og derfor kan vi tillade os at se bort fra lydhastigheds termer.”

$$\ddot{\delta}^{(2)} + \frac{2}{\tau}\dot{\delta}^{(2)} - \frac{6}{\tau^2}\delta_M^{(2)} = D\frac{3}{2}H_0^2\Big(2\partial_j\nabla^{-2}\tilde{\delta}_M^{(1)}\partial_j\tilde{\delta}^{(1)} + 2\tilde{\delta}^{(1)}\tilde{\delta}_M^{(1)}\Big) \tag{4.72}$$

$$+4\dot{D}^2\Big(\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\partial_j\tilde{\delta}^{(1)} + 2\tilde{\delta}^{(1)}\tilde{\delta}^{(1)} + 2\partial_i\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\partial_i\partial_j\nabla^{-2}\tilde{\delta}^{(1)}\Big) \tag{4.73}$$