

$$T = \frac{1}{2} \dot{\theta}_1^2 + \frac{1}{2} \dot{\theta}_2^2 = \frac{1}{2} \dot{Q}_1^2 + \frac{1}{2} \dot{Q}_2^2 \text{ (check this!)}$$

Equations of motion  $\ddot{Q}_1 = -\omega_1^2 Q_1$   
 $\ddot{Q}_2 = -(1+2\alpha) Q_2$

$$\Rightarrow Q_1 = a_1 \cos t + b_1 \sin t$$
$$Q_2 = a_2 \cos \omega_2 t + b_2 \sin \omega_2 t \quad \omega_2^2 = 1+2\alpha$$

$$\theta_1 = \frac{Q_1 + Q_2}{\sqrt{2}} \quad \theta_2 = \frac{Q_1 - Q_2}{\sqrt{2}}$$

$a_1, b_1, a_2, b_2$  are determined by the initial conditions

### Vc) zero modes

What is the meaning of zero frequencies?

$$\omega_k = 0 \Rightarrow \ddot{Q}_k = 0 \Rightarrow Q_k = a + bt$$

This is motion with constant velocity.  
All atoms move in the same direction

