



dofs.  $x_1, v_1$   $x_2, v_2$  12 dof (3x4)

$m$   
 $u, m$

$f=ma$

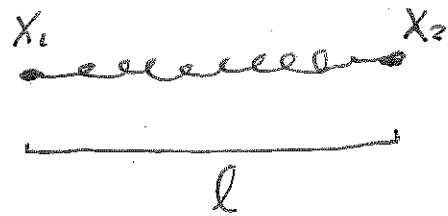
Mass:  $M_1, M_2$   
↑  
given

$a_1 = \ddot{x}_1 = \dot{v}_1$   
 $a_2 = \ddot{x}_2 = \dot{v}_2$

$M_1 \ddot{x}_1 = f_1$        $M_2 \ddot{x}_2 = f_2$

$f_2 = -f_1$  ← equal and opposite  
along direction of spring

$\vec{u} = \frac{x_2 - x_1}{\|x_2 - x_1\|}$  direction of spring



$f_1 = k \left( \frac{l}{l_0} \right) \vec{u}$        $h(1) = 0$

rest length  $l_0$

if  $l = l_0$ , then  $f_1 = f_2 = 0$

$h(r) = k(r - 1)$

$f_1 = \pm k \left( \frac{l}{l_0} - 1 \right) \vec{u}$

$$f_1 = +k \left( \frac{\|x_2 - x_1\|}{l_0} - 1 \right) \frac{x_2 - x_1}{\|x_2 - x_1\|}$$

$$f_2 = -k \left( \frac{\|x_2 - x_1\|}{l_0} - 1 \right) \frac{x_2 - x_1}{\|x_2 - x_1\|}$$



if  $x_1 = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$   $x_2 = \begin{pmatrix} w \\ 0 \\ 0 \end{pmatrix}$

$w$  is  $> 0$

$$f_1 = \begin{pmatrix} k \\ 0 \\ 0 \end{pmatrix}$$

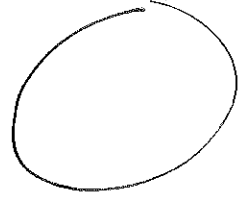
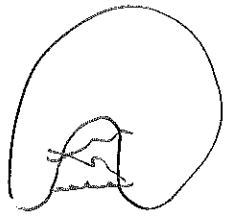
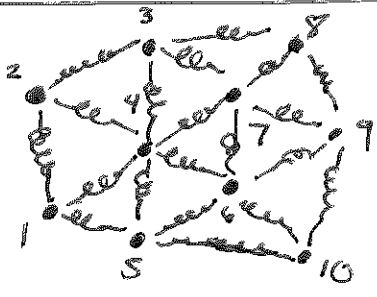
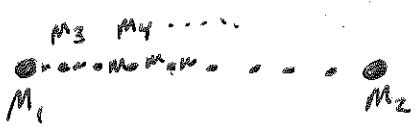
should have  $f > 0$

$$g = \begin{pmatrix} 0 \\ -9.8 \text{ m/s}^2 \\ 0 \end{pmatrix}$$

$$m_1 \ddot{x}_1 = k \left( \frac{\|x_2 - x_1\|}{l_0} - 1 \right) \frac{x_2 - x_1}{\|x_2 - x_1\|} + m_1 g$$

$$m_2 \ddot{x}_2 = -k \left( \frac{\|x_2 - x_1\|}{l_0} - 1 \right) \frac{x_2 - x_1}{\|x_2 - x_1\|} + m_2 g$$

↑  
gravity



$x_1 \dots x_{10}$   
 $v_1 \dots v_{10}$

$$m_1 \ddot{x}_1 = f_1 = f_{12} + f_{14} + f_{15}$$

