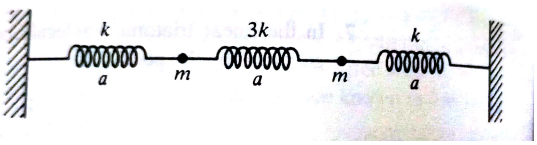
# EP 222: Classical Mechanics
# Tutorial Sheet 6

This tutorial sheet contains problems related to small oscillations of coupled harmonic oscillators, their eigenfrequencies, and normal modes.

1. Consider a double pendulum composed of two identical pendula of massless rods of length $l$, and masses $m$, attached along the vertical direction. Obtain the frequencies of the normal modes and the normal coordinates for small oscillations of this system.

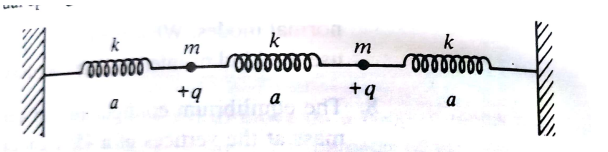
2. Two particles move in one dimension at the junction of three springs, as shown in the figure. The springs all have unstretched lengths equal to $a$, and the force constants and masses are shown. Find their eigenfrequencies, and normal modes.






3. Two mass points of equal mass $m$ are connected to each other and to fixed points by three equal springs of force constant $k$, as shown in the diagram. The equilibrium length of each sprint is $a$. Each mass point has charge $+q$, and they repel each other according to Coulomb law. Set up the secular equation for the eigenfrequencies.






4. A plane triatomic molecule consists of equal masses m at vertices of an equilateral triangle of sides $a$. Assume the molecule is held together by forces that are harmonic

for small oscillations and that the force constants are identical and equal to $k$. Allow motion only in the plane of the molecule.

(a) Set up the secular equation for the eigenfrequencies of the system.

(b) Identify the zero frequency modes of this system.