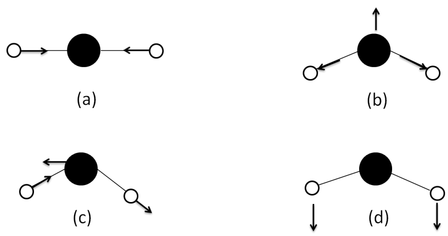
**DEPARTMENT OF PHYSICS**
**Indian Institute of Technology Kharagpur**
**Classical Mechanics-I**
**Course: PH20007**
**Assignment-11: Assignment-12 (Small oscillation-2)**

1. The kinetic and potential energy matrices for a system executing small oscillation
(a) are with all imaginary elements
(b) have all elements real and positive
(c) must have a determinant equal to 1
(d) has at least one imaginary eigenvalue

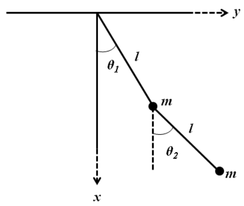
2. The P.E. of a particle is given by $V(x) = x^4 - 4x^3 - 8x^2 + 48x$. The points of stable and unstable equilibrium are
(a) stable at $x = 0$. Unstable at $x = 2$
(a) stable at $x = 3$. Unstable at $x = \pm 2$
(c) stable at $x = 2, 3$. Unstable at $x = -2$
(d) stable at $x = -2, 3$. Unstable at $x = 2$

3. For vibrations of a tri-atomic molecule in figure, which of the following figures does NOT represent a normal mode of vibration?

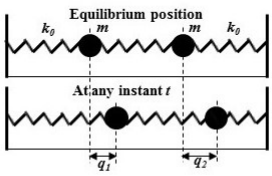



(a)
(b)
(c)
(d)

4. A double pendulum is constructed by hanging one pendulum from the bob of another pendulum (shown in figure). For a double pendulum system if both pendula has equal mass ($m$) and length ($l$), frequencies of small oscillation are: (take $\theta_1$ and $\theta_2$ as generalised coordinate)
(a) $\omega = \sqrt{\frac{(2\pm\sqrt{2})l}{g}}$
(b) $\omega = \sqrt{\frac{(2\pm\sqrt{2})g}{l}}$
(c) $\omega = 0$ *and* $\sqrt{\frac{(2-\sqrt{2})g}{l}}$
(d) $\omega = 0$ *and* $\sqrt{\frac{(2+\sqrt{2})g}{l}}$

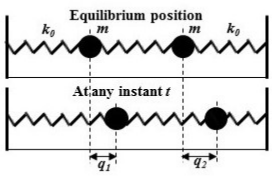



5. Two equal masses $m$ are connected by springs of spring constant $k_0$ so that the masses are free to slide on a frictionless table. The ends of the springs are attached to the fixed walls as shown in figure. The normal frequencies are




(a) $\omega_1 = \sqrt{\frac{k_0}{m}}, \omega_2 = \sqrt{\frac{3k_0}{m}}$
(b) $\omega_1 = \sqrt{\frac{k_0}{3m}}, \omega_2 = \sqrt{\frac{3k_0}{m}}$
(c) $\omega_1 = \sqrt{\frac{k_0}{m}}, \omega_2 = \sqrt{\frac{2k_0}{m}}$
(d) $\omega_1 = \sqrt{\frac{2k_0}{m}}, \omega_2 = \sqrt{\frac{3k_0}{m}}$

6. Two equal masses $m$ are connected by springs of spring constant $k_0$ so that the masses are free to slide on a frictionless table. The ends of the springs are attached to the fixed walls as shown in figure. The normalmodes of vibrations (i.e. eigen vectors corresponding to the normal frequencies) are




(a) $a_1 = \frac{1}{\sqrt{2m}} \begin{bmatrix} 0 \\ 1 \end{bmatrix}, a_2 = \frac{1}{\sqrt{2m}} \begin{bmatrix} 1 \\ 0 \end{bmatrix}$
(b) $a_1 = \frac{1}{\sqrt{2m}} \begin{bmatrix} 1 \\ -1 \end{bmatrix}, a_2 = \frac{1}{\sqrt{2m}} \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

(c) $a_1 = \frac{1}{\sqrt{2m}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}, a_2 = \frac{1}{\sqrt{2m}} \begin{bmatrix} 1 \\ -1 \end{bmatrix}$

(d) $a_1 = \frac{1}{\sqrt{2m}} \begin{bmatrix} 2 \\ 1 \end{bmatrix}, a_2 = \frac{1}{\sqrt{2m}} \begin{bmatrix} 2 \\ -1 \end{bmatrix}$

7. To solve the problem of stretching of linear triatomic molecule (Shown in Figure , also discussed in class) in center of mass frame, we shall define a new set of coordinates; namely $Q_1 = \frac{q_1+q_2}{\sqrt{2}}$ and $Q_2 = \frac{q_1-q_2}{\sqrt{2}}$; correspond to symmetric and asymmetric stretching modes, respectively. $q_1$ and $q_2$ are measured w.r.t the central atom, which is considered immobile. Also, we need an extra term $\frac{1}{2}\alpha Q_2^2$ in the potential energy expression. The frequencies of normal oscillation are

(a) $\omega = \sqrt{\frac{k}{m}}, \sqrt{\frac{k+\alpha}{m}}$

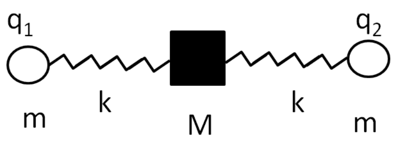



Figure 4

(b) $\omega = 0, \sqrt{\frac{k}{m}}$

(c) $\omega = \sqrt{\frac{k}{m}}, \sqrt{\frac{k-\alpha}{m}}$

(d) $\omega = -\sqrt{\frac{k}{m}}, \sqrt{\frac{k-\alpha}{m}}$

8. Compare the result of the above problem with the frequency values we obtained in the classroom problem and then the value of the additional spring constant $\alpha$ of asymmetric stretching is

(a) $\frac{2m}{M}$

(b) $\frac{2kM}{m}$

(c) $\frac{2m}{kM}$

(d) $\frac{2km}{M}$

9. Two identical simple pendulums each having length $l$ and a bob of mass $m$, are coupled to each other by a horizontal massless spring of spring constant $k$. The spring is unstretched when the two bobs are in equilibrium. The normal frequencies are

(a) $\omega = -\sqrt{\frac{g}{l}}, \sqrt{\frac{g}{l} + \frac{2k}{m}}$

(b) $\omega = \sqrt{\frac{g}{l}}, \sqrt{\frac{g}{l} + \frac{2k}{m}}$

(c) $\omega = \sqrt{\frac{g}{l}}, \sqrt{\frac{g}{l} - \frac{2k}{m}}$

(d) $\omega = \sqrt{\frac{g}{l}}, -\sqrt{\frac{g}{l} + \frac{2k}{m}}$

10. A three simple pendulum (Three coupled pendulum) each having length $l$ and a bob of mass $m$, coupled to each other with massless springs having same spring constant $k$. The normal

frequencies are

(a) $\omega = \sqrt{\frac{g}{l} + \frac{2k}{m}}, \sqrt{\frac{g}{l} - \frac{k}{m}}$

(b) $\omega = \sqrt{\frac{g}{l} + \frac{2k}{m}}, \sqrt{\frac{g}{l} + \frac{2k}{m}}$

(c) $\omega = \sqrt{\frac{g}{l} + \frac{2k}{m}}, \sqrt{\frac{g}{l} + \frac{2k}{m}}, \sqrt{\frac{g}{l} - \frac{k}{m}}$

(d) $\omega = \sqrt{\frac{g}{l} + \frac{2k}{m}}, \sqrt{\frac{g}{l} - \frac{2k}{m}}, \sqrt{\frac{g}{l} - \frac{k}{m}}$

End