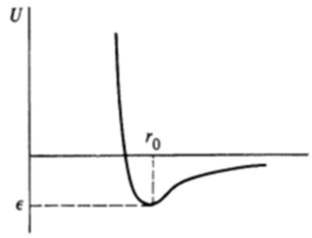
1. A commonly used potential energy function to describe the interaction between two atoms (say, each of mass, *m*) is the Lennard-Jones potential,



$$U = \varepsilon\left[\left(\frac{r_0}{r}\right)^{12} - 2\left(\frac{r_0}{r}\right)^{6}\right]$$

where *r* is the separation between the particles, r_0 and ε are constants. Show that the potential minimum correspond to the separation, r_0, and that the depth of the potential well is ε. Find (a) the potential energy and (b) the x-component of the force acting on atom A due to atom B, if A and B are located respectively at (r_0, 0, 0) and ($2r_0$, r_0, 0).

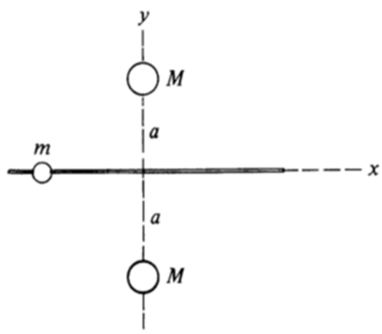
2. The potential energy function for a particular two dimensional force field is given by $U = Cxe^{-y}$, where C is a constant. (a) Sketch the constant energy lines. (b) Show that if a point is displace by a short distance *dx* along a constant energy line, then its total displacement is $\boldsymbol{dr} = dx(\hat{\boldsymbol{\imath}} + \frac{\hat{\boldsymbol{\jmath}}}{x})$. (c) Using result of (b) show explicitly that $\boldsymbol{\nabla} U$ is perpendicular to the constant energy line.

3. When the flattening of the earth at the poles is taken into account, it is found that the gravitational potential energy of a mass m a distance r from the center of the earth is approximately,

$$U = -\frac{GMm}{r}\left[1 - 5.4 \times 10^{-4}\left(\frac{R}{r}\right)^2 (3cos^2\theta - 1)\right]$$

where θ is measured from the pole. Show that there is a small tangential gravitational force on *m* except above the poles or the equator. Find the ratio of this force to $-GMm/r^2$ for θ = 45° and $r = R$.

4. A bead of mass m slides without friction on a smooth rod along the x-axis. The rod is equidistant between two spheres of mass M. The spheres are located at x=0, y= ± a as shown, and attract the bead gravitationally.



   a. Find the potential energy and force on the bead when it is at $x = -\sqrt{3}\ a$.
   b. Find the frequency of small oscillation of the bead around the equilibrium.

5. Determine if the following forces are conservative:
   a) $F_a = B(y^2\hat{\imath} - x^2\hat{\jmath})$, where B is a constant.
   b) $F_b = -Ar^3\hat{r}$, where A is a constant.
   c) $F_c = (y^2\cos x + z^3)\hat{\imath} + (2y\sin x - 4)\,\hat{\jmath} + (3xz^2 + 2)\hat{k}$