Tutorial # 2

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PH 101: Physics I (2019)

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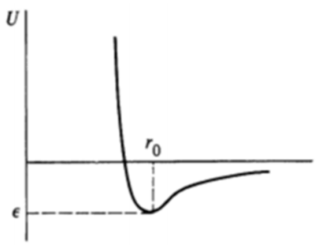
1. A commonly used potential energy function (U) to describe the interaction between two atoms (say, each of mass, m) is the Lennard-Jones potential, $U = \epsilon\left[\left(\frac{r_0}{r}\right)^{12} - 2\left(\frac{r_0}{r}\right)^{6}\right]$, where r is the separation between the particles, r_0 and ϵ are constants. Show that the potential minimum corresponds to the separation, r_0, and 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 $(2r_0, r_0, 0)$.

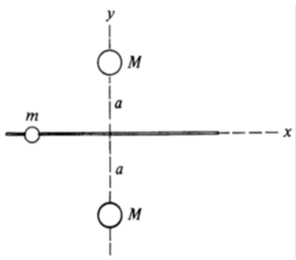


2. When the flattening of the earth at the poles is taken into account, it is found that the gravitational potential energy (U) of a mass m resides at a distance r from the center of the earth is approximately given by,

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

where the angle θ is measured from the pole. Show that there exists a small tangential gravitational force on m except above the poles or the equator. Find the ratio between this force and $\frac{GMm}{r^2}$ for $\theta = 45^\circ$ and $r = R$.

3. 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 $x = 0$, $y = \pm a$ 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.



4. Determine if the following forces are conservative:

   (a) $F_a = B\left(y^2\hat{i} - x^2\hat{j}\right)$, where B is a constant.

   (b) $F_b = -Ar^3\hat{r}$, where A is a constant.

   (c) $F_c = \left(y^2\cos\, x + z^3\right)\hat{i} + \left(2y\sin\, x - 4\right)\hat{j} + \left(3xz^2 + 2\right)\hat{k}$

5. A car is driven on a large revolving platform which rotates with constant angular speed ω. At $t = 0$, the car leaves the origin and follows a line painted radially outwards on the platform with constant speed v_0 . Total weight of the car is W and the coefficient of friction between car and the platform is μ.

   (a) Find the acceleration of the car as a function of time.

   (b) Find the time at which the car starts to skid.

   (c) Find the direction of the frictional force when the car starts to skid.