$$V = -\frac{k}{2}(x_1^2 + x_2^2)$$

According to problem 3
the classical trajectories are given by

$$x_i(H\delta_{ij} - \tfrac{1}{2}A_{ij})x_j = \frac{|\vec{M}|^2}{2} \quad (1)$$

$A_{11} = 2E_1 = -kx_1^2 + p_1^2$
$A_{22} = 2E_2 = -kx_2^2 + p_2^2$
$A_{12} = -kx_1x_2 + p_1p_2$

We have to show that (1) represent a hyperbola with asymptotes through $x_1 = x_2 = 0$.
We only have to show that
$E\delta_{ij} - \frac{1}{2}A_{ij}$ has one positive and one negative eigenvalue

$\det(E - \frac{1}{2}A_{ij} - \lambda) \Rightarrow$
$\lambda^2 - \lambda(E_1 + E_2) + E_1E_2 \quad - \frac{1}{4}(-kx_1x_2 + p_1p_2)^2 = 0$
$\Rightarrow$

$$\Rightarrow -\frac{k}{4}(x_1p_2 - x_2p_1)^2 + \lambda^2 - \lambda(E_1 + E_2) = 0$$

$$E - \lambda_{1,2} = +\frac{E_1 + E_2 \pm \sqrt{(E_1 + E_2)^2 + k(x_1p_2 - x_2p_1)^2}}{2}$$

note

$\Rightarrow$ we have one positive and one negative eigenvalue
For $k < 0$ $x_1 > 0$ and $x_2 > 0$; then ellipse