

which is of mixed  $F_2, F_1$  type. This is Legendre-transformed into a function of the  $F_1$  type according to

$$F_1(q_1, Q_1, q_2, Q_2) = F_{12} + p_1 q_1.$$

The least action principle then says

$$\begin{aligned} p_1 \dot{q}_1 + p_2 \dot{q}_2 - H(q_1, p_1) &= P_1 \dot{Q}_1 + P_2 \dot{Q}_2 - K(Q_1, P_1) + \frac{\partial F_{12}}{\partial p_1} \dot{p}_1 + \frac{\partial F_{12}}{\partial Q_1} \dot{Q}_1 \\ &\quad + \frac{\partial F_{12}}{\partial q_2} \dot{q}_2 + \frac{\partial F_{12}}{\partial Q_2} \dot{Q}_2 + p_1 \dot{q}_1 + q_1 \dot{p}_1 \end{aligned}$$

whence clearly

$$\begin{aligned} q_1 &= -\frac{\partial F_{12}}{\partial p_1} = Q_1 && \checkmark \\ P_1 &= -\frac{\partial F_{12}}{\partial Q_1} = -p_1 - 2Q_2 && \\ &= -p_1 - 2p_2 && \checkmark \\ p_2 &= \frac{\partial F_{12}}{\partial q_2} = Q_2 && \checkmark \\ P_2 &= -\frac{\partial F_{12}}{\partial Q_2} = -2Q_1 - q_2 = -2q_1 - q_2 && \checkmark. \end{aligned}$$

### Problem 9.14

By any method you choose show that the following transformation is canonical:

$$\begin{aligned} x &= \frac{1}{\alpha}(\sqrt{2P_1} \sin Q_1 + P_2), & p_x &= \frac{\alpha}{2}(\sqrt{2P_1} \cos Q_1 - Q_2) \\ y &= \frac{1}{\alpha}(\sqrt{2P_1} \cos Q_1 + Q_2), & p_y &= -\frac{\alpha}{2}(\sqrt{2P_1} \sin Q_1 - P_2) \end{aligned}$$

where  $\alpha$  is some fixed parameter.

Apply this transformation to the problem of a particle of charge  $q$  moving in a plane that is perpendicular to a constant magnetic field  $\mathbf{B}$ . Express the Hamiltonian for this problem in the  $(Q_1, P_1)$  coordinates, letting the parameter  $\alpha$  take the form

$$\alpha^2 = \frac{qB}{c}.$$

From this Hamiltonian obtain the motion of the particle as a function of time.

We will prove that the transformation is canonical by finding a generating function. Our first step to this end will be to express everything as a function

# Goldstein Classical Mechanics Solutions Chapter 9

**Emilie Sanchez**



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