Theoretical Dynamics

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Homework 3

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1 Goldstein 8.1

1.1 Part (a)

The Hamiltonian is given by

$$H(q_i, p_i, t) = p_i \dot{q}_i - L(q_i, \dot{q}_i, t)$$
 (1)

where all the \dot{q}_i 's on the RHS are to be expressed in terms of q_i , p_i and t. Now,

$$dH = \frac{\partial H}{\partial q_i}dq_i + \frac{\partial H}{\partial p_i}dp_i + \frac{\partial H}{\partial t}dt$$
 (2)

From (1).

$$dH = p_i d\hat{q}_i + \hat{q}_i dp_i - dL$$

$$= p_i d\hat{q}_i + \hat{q}_i dp_i - \left(\frac{\partial L}{\partial q_i} dq_i + \frac{\partial L}{\partial \hat{q}_i} d\hat{q}_i + \frac{\partial L}{\partial t} dt\right)$$

$$= -\frac{\partial L}{\partial q_i} dq_i + \hat{q}_i dp_i + \left(p_i - \frac{\partial L}{\partial \hat{q}_i}\right) d\hat{q}_i - \frac{\partial L}{\partial t} dt \qquad (3)$$

Comparing (2) and (3) we get

$$\frac{\partial H}{\partial q_i} = -\frac{\partial L}{\partial q_i} = -\hat{p}_i$$
 (2nd equality from Hamilton's equation) (4)

$$\dot{q}_i = \frac{\partial H}{\partial q_i}$$
 (also Hamilton's equation) (5)

$$p_i - \frac{\partial L}{\partial \hat{q}_i} = 0$$
 (H is not explicitly dependent on \hat{q}_i) (6)

$$-\frac{\partial L}{\partial t} = \frac{\partial H}{\partial t}$$
(7)

From (4) and (6) we have

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q_i} = 0, \quad i = 1, 2, ..., n$$
 (8)

which are the Euler-Lagrange equations.

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