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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- 1. Understanding the eBook Goldstein Classical Mechanics Solutions Chapter 8
 - The Rise of Digital Reading Goldstein Classical Mechanics Solutions Chapter 8
 - Advantages of eBooks Over Traditional Books
- 2. Identifying Goldstein Classical Mechanics Solutions Chapter 8
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
- 3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Goldstein Classical Mechanics Solutions Chapter 8
 - User-Friendly Interface
- 4. Exploring eBook Recommendations from Goldstein Classical Mechanics Solutions Chapter 8

- Personalized Recommendations
- Goldstein Classical Mechanics Solutions Chapter 8 User Reviews and Ratings
- Goldstein Classical Mechanics Solutions Chapter 8 and Bestseller Lists
- 5. Accessing Goldstein Classical Mechanics Solutions Chapter 8 Free and Paid eBooks
 - Goldstein Classical Mechanics Solutions Chapter 8 Public Domain eBooks
 - Goldstein Classical Mechanics Solutions Chapter 8 eBook Subscription Services
 - Goldstein Classical Mechanics Solutions Chapter 8 Budget-Friendly Options
- 6. Navigating Goldstein Classical Mechanics Solutions Chapter 8 eBook Formats
 - o ePub, PDF, MOBI, and More
 - Goldstein Classical Mechanics Solutions Chapter 8 Compatibility with Devices
 - Goldstein Classical Mechanics Solutions Chapter 8 Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Goldstein Classical Mechanics Solutions Chapter 8
 - Highlighting and Note-Taking Goldstein Classical Mechanics Solutions Chapter 8
 - Interactive Elements Goldstein Classical Mechanics Solutions Chapter 8
- 8. Staying Engaged with Goldstein Classical Mechanics Solutions Chapter 8
 - o Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Goldstein Classical Mechanics Solutions Chapter 8
- 9. Balancing eBooks and Physical Books Goldstein Classical Mechanics Solutions Chapter 8
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Goldstein Classical Mechanics Solutions Chapter 8
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Goldstein Classical Mechanics Solutions Chapter 8
 - Setting Reading Goals Goldstein Classical Mechanics Solutions Chapter 8
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Goldstein Classical Mechanics Solutions Chapter 8

- Fact-Checking eBook Content of Goldstein Classical Mechanics Solutions Chapter 8
- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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