

CHAPTER 12 MOTION ALONG A CURVE

12.1 The Position Vector (page 452)

This section explains the key vectors that describe motion. They are functions of t . In other words, the time is a "parameter." We know more than the path that the point travels along. We also know where the point is at every time t . So we can find the velocity (by taking a derivative).

In Chapter 1 the velocity $v(t)$ was the derivative of the distance $f(t)$. That was in one direction, along a line. Now $f(t)$ is replaced by the **position vector** $\mathbf{R}(t)$. Its derivative is the **velocity vector** $\mathbf{v}(t)$:

$$\text{position } \mathbf{R}(t) = x(t)\mathbf{i} + y(t)\mathbf{j} + z(t)\mathbf{k} \qquad \text{velocity } \mathbf{v}(t) = \frac{d\mathbf{R}}{dt} = \frac{dx}{dt}\mathbf{i} + \frac{dy}{dt}\mathbf{j} + \frac{dz}{dt}\mathbf{k}.$$

The next derivative is the **acceleration vector** $\mathbf{a} = d\mathbf{v}/dt$.

The direction of \mathbf{v} is a unit vector $\frac{\mathbf{v}}{|\mathbf{v}|}$. This is the **tangent vector** \mathbf{T} . It is tangent to the path because \mathbf{v} is tangent to the path. But it does not tell us the speed because we divide by $|\mathbf{v}|$; the length is always $|\mathbf{T}| = 1$. The length $|\mathbf{v}|$ is the speed ds/dt . Integrate to find the distance traveled. Remember: \mathbf{R} , \mathbf{v} , \mathbf{a} , \mathbf{T} are vectors.

Read-throughs and selected even-numbered solutions:

The position vector $\mathbf{R}(t)$ along the curve changes with the parameter t . The velocity is $d\mathbf{R}/dt$. The acceleration is $d^2\mathbf{R}/dt^2$. If the position is $\mathbf{i} + t\mathbf{j} + t^2\mathbf{k}$, then $\mathbf{v} = \mathbf{j} + 2t\mathbf{k}$ and $\mathbf{a} = 2\mathbf{k}$. In that example the speed is $|\mathbf{v}| = \sqrt{1 + 4t^2}$. This equals ds/dt , where s measures the distance along the curve. Then $s = \int (ds/dt)dt$.

The tangent vector is in the same direction as the velocity, but \mathbf{T} is a unit vector. In general $\mathbf{T} = \mathbf{v}/|\mathbf{v}|$ and in the example $\mathbf{T} = (\mathbf{j} + 2t\mathbf{k})/\sqrt{1 + 4t^2}$.

Steady motion along a line has $\mathbf{a} = \mathbf{0}$. If the line is $x = y = z$, the unit tangent vector is $\mathbf{T} = (\mathbf{i} + \mathbf{j} + \mathbf{k})/\sqrt{3}$. If the speed is $|\mathbf{v}| = \sqrt{3}$, the velocity vector is $\mathbf{v} = \mathbf{i} + \mathbf{j} + \mathbf{k}$. If the initial position is $\{1, 0, 0\}$, the position vector is $\mathbf{R}(t) = \{1 + t\}\mathbf{i} + t\mathbf{j} + t\mathbf{k}$. The general equation of a line is $x = x_0 + tv_1$, $y = y_0 + tv_2$, $z = z_0 + tv_3$. In vector notation this is $\mathbf{R}(t) = \mathbf{R}_0 + t\mathbf{v}$. Eliminating t leaves the equations $(x - x_0)/v_1 = (y - y_0)/v_2 = (z - z_0)/v_3$. A line in space needs two equations where a plane needs one. A line has one parameter where a plane has two. The line from $\mathbf{R}_0 = \{1, 0, 0\}$ to $\{2, 2, 2\}$ with $|\mathbf{v}| = 3$ is $\mathbf{R}(t) = \{1 + t\}\mathbf{i} + 2t\mathbf{j} + 2t\mathbf{k}$.

Steady motion around a circle (radius r , angular velocity ω) has $x = r \cos \omega t$, $y = r \sin \omega t$, $z = 0$. The velocity is $\mathbf{v} = -r\omega \sin \omega t \mathbf{i} + r\omega \cos \omega t \mathbf{j}$. The speed is $|\mathbf{v}| = r\omega$. The acceleration is $\mathbf{a} = -r\omega^2(\cos \omega t \mathbf{i} + \sin \omega t \mathbf{j})$, which has magnitude $r\omega^2$ and direction toward $(0, 0)$. Combining upward motion $\mathbf{R} = t\mathbf{k}$ with this circular motion produces motion around a helix. Then $\mathbf{v} = -r\omega \sin \omega t \mathbf{i} + r\omega \cos \omega t \mathbf{j} + \mathbf{k}$ and $|\mathbf{v}| = \sqrt{1 + r^2\omega^2}$.

- 2 The path is the line $x + y = 2$. The speed is $\sqrt{(dx/dt)^2 + (dy/dt)^2} = \sqrt{2}$.
- 10 The line is $(x, y, z) = \{3, 1, -2\} + t\{-1, -\frac{1}{2}, \frac{2}{3}\}$. Then at $t = 3$ this gives $\{0, 0, 0\}$. The speed is $\frac{\text{distance}}{\text{time}} = \sqrt{2\frac{1}{9} + 1 + 4} = \sqrt{\frac{14}{9}}$. For speed c choose $(x, y, z) = \{3, 1, -2\} + \frac{c}{\sqrt{14}}\{-2, -1, 2\}$.
- 14 $x^2 + y^2 = (1 + t)^2 + (2 - t)^2$ is a minimum when $2(1 + t) - 2(2 - t) = 0$ or $4t = 2$ or $t = \frac{1}{2}$. The path crosses $y = x$ when $1 + t = 2 - t$ or $t = \frac{1}{2}$ (again) at $x = y = \frac{3}{2}$. The line never crosses a parallel line like $x = 2 + t$, $y = 2 - t$.
- 20 If $x \frac{dx}{dt} + y \frac{dy}{dt} = 0$ along a path then $\frac{d}{dt}(x^2 + y^2) = 0$ and $x^2 + y^2 = \text{constant}$.

Chapter 12 Motion Problems

Barnett Rich



Chapter 12 Motion Problems:

Motion Analysis and Image Sequence Processing M. Ibrahim Sezan,Reginald L. Lagendijk,2012-12-06 An image or video sequence is a series of two dimensional 2 D images sequen tially ordered in time Image sequences can be acquired for instance by video motion picture X ray or acoustic cameras or they can be synthetically gen erated by sequentially ordering 2 D still images as in computer graphics and animation The use of image sequences in areas such as entertainment visual communications multimedia education medicine surveillance remote control and scientific research is constantly growing as the use of television and video systems are becoming more and more common The boosted interest in digital video for both consumer and professional products along with the availability of fast processors and memory at reasonable costs has been a major driving force behind this growth Before we elaborate on the two major terms that appear in the title of this book namely motion analysis and image sequence processing we like to place them in their proper contexts within the range of possible operations that involve image sequences In this book we choose to classify these operations into three major categories namely i image sequence processing ii image sequence analysis and iii visualization The interrelationship among these three categories is pictorially described in Figure 1 below in the form of an image sequence triangle

Handbook of Marine Craft Hydrodynamics and Motion Control Thor I. Fossen,2021-03-22 Handbook of MARINE CRAFT HYDRODYNAMICS AND MOTION CONTROL The latest tools for analysis and design of advanced GNC systems Handbook of Marine Craft Hydrodynamics and Motion Control is an extensive study of the latest research in hydrodynamics guidance navigation and control systems for marine craft The text establishes how the implementation of mathematical models and modern control theory can be used for simulation and verification of control systems decision support systems and situational awareness systems Coverage includes hydrodynamic models for marine craft models for wind waves and ocean currents dynamics and stability of marine craft advanced guidance principles sensor fusion and inertial navigation This important book includes the latest tools for analysis and design of advanced GNC systems and presents new material on unmanned underwater vehicles surface craft and autonomous vehicles References and examples are included to enable engineers to analyze existing projects before making their own designs as well as MATLAB scripts for hands on software development and testing Highlights of this Second Edition include Topical case studies and worked examples demonstrating how you can apply modeling and control design techniques to your own designs A Github repository with MATLAB scripts MSS toolbox compatible with the latest software releases from Mathworks New content on mathematical modeling including models for ships and underwater vehicles hydrostatics and control forces and moments New methods for guidance and navigation including line of sight LOS guidance laws for path following sensory systems model based navigation systems and inertial navigation systems This fully revised Second Edition includes innovative research in hydrodynamics and GNC systems for marine craft from ships to autonomous vehicles operating on the surface and under water Handbook of Marine Craft

Hydrodynamics and Motion Control is a must have for students and engineers working with unmanned systems field robots autonomous vehicles and ships MSS toolbox <https://github.com/cybergalactic/mss> Lecture notes <https://www.fossen.biz/wiley> Author's home page <https://www.fossen.biz> **Principles of Engineering Mechanics** Millard F. Beatty, 2010-06-01

Separation of the elements of classical mechanics into kinematics and dynamics is an uncommon tutorial approach but the author uses it to advantage in this two volume set Students gain a mastery of kinematics first a solid foundation for the later study of the free body formulation of the dynamics problem A key objective of these volumes which present a vector treatment of the principles of mechanics is to help the student gain confidence in transforming problems into appropriate mathematical language that may be manipulated to give useful physical conclusions or specific numerical results In the first volume the elements of vector calculus and the matrix algebra are reviewed in appendices Unusual mathematical topics such as singularity functions and some elements of tensor analysis are introduced within the text A logical and systematic building of well known kinematic concepts theorems and formulas illustrated by examples and problems is presented offering insights into both fundamentals and applications Problems amplify the material and pave the way for advanced study of topics in mechanical design analysis advanced kinematics of mechanisms and analytical dynamics mechanical vibrations and controls and continuum mechanics of solids and fluids Volume I of Principles of Engineering Mechanics provides the basis for a stimulating and rewarding one term course for advanced undergraduate and first year graduate students specializing in mechanics engineering science engineering physics applied mathematics materials science and mechanical aerospace and civil engineering Professionals working in related fields of applied mathematics will find it a practical review and a quick reference for questions involving basic kinematics *EBOOK: Vector Mechanics for Engineers: Dynamics (SI)* Ferdinand Beer, E. Johnston, Phillip Cornwell, 2013-04-16 Continuing in the spirit of its successful previous editions the tenth edition of Beer Johnston Mazurek and Cornwell's Vector Mechanics for Engineers provides conceptually accurate and thorough coverage together with a significant refreshment of the exercise sets and online delivery of homework problems to your students Nearly forty percent of the problems in the text are changed from the previous edition The Beer Johnston textbooks introduced significant pedagogical innovations into engineering mechanics teaching The consistent accurate problem solving methodology gives your students the best opportunity to learn statics and dynamics At the same time the careful presentation of content unmatched levels of accuracy and attention to detail have made these texts the standard for excellence System-specific PI Control Theory for Fluid and Motion Systems Kalman I. Krakow, 2006 A system specific feedback control theory for fluid process control and for motion control has been developed to enable analytical tuning The system specific theory enables the determination of the coefficients required to implement i.e. tune a proportional integral PI control system analytically from physical characteristics of the fluid or motion system PI control is essentially PID control with the derivative D coefficient set equal to zero A derivative coefficient is not essential and may have a detrimental effect

on system response characteristics System specific theory based on the fundamental algorithm for PID control systems was developed from a back to basics perspective considering digital not analog control of fluid systems and motion systems independently For additional information visit [www control innovation com](http://www.controlinnovation.com) ControlProblems is an application containing numerical system models corresponding to the problems presented in Chapters 23 though 27 of this book The problems represent typical systems that may be analyzed with system specific PI control theory The application enables validation of proportional integral PI coefficient calculations as well as investigation of system response characteristics with various PI coefficients Numerical data for the problems is presented in the ControlProblems application This data may be changed by the user to simulate different PI coefficients modulated capacities complete response intervals signal update intervals loads etc Suitability of user specified PI coefficients may be evaluated from simulated system response characteristics System response characteristic for default PI coefficients may be used for comparison The application is designed for computers running a Windows 98 or later operating system The download is a zip file ControlProblems zip containing the application in a file titled ControlProblems exe files required to run the exe file and files required to install and remove the application The following download and setup procedure is required The download should be saved in its own folder e g C ControlProblems or C Temp The files contained in the zip file should be extracted to the same folder Run setup exe to install the application Download ControlProblems zip file name 1581129211_extra_material zip approximately 500 KB ControlProblems

Hierarchical Methods V. Kulish, 2006-04-11 The book consists of two Volumes The first the preceding volume is devoted to the general nonlinear theory of the hierarchical dynamic oscillative wave systems This theory has been called the theory of hierarchical oscillations and waves Here two aspects of the proposed theory are discussed The first aspects concern the fundamental nature and the basic concepts and ideas of a new hierarchical approach to studying hierarchical dynamic systems A new hierarchical paradigm is proposed as a basis of a new point of view of such types of systems In turn a set of hierarchical principles is formulated as the fundamental basis of this paradigm Therein the self resemblance holographic principle plays a key role here An adequate mathematic description factorization of the proposed paradigm is carried out The concepts of structural and dynamic functional operators are put into the basis of this description Electrodynamics is chosen as a convenient basis for an obvious demonstration of some key points of the proposed new theory The second aspect has a purely mathematical nature It is related to the form of factorization i e mathematical description of hierarchical types of dynamic models and discussion of the methods of their mathematical analysis A set of the hierarchical asymptotic analytical numerical methods is given as an evidence of the practical effectiveness of the proposed version of hierarchical theory

Fundamentals of Physics, , Problem Supplement No. 1 David Halliday, Robert Resnick, Jearl Walker, 2000-06-06 No other book on the market today can match the success of Halliday Resnick and Walker's Fundamentals of Physics In a breezy easy to understand style the book offers a solid understanding of fundamental physics concepts and helps readers apply this

conceptual understanding to quantitative problem solving **Schaum's Outline of Physics for Engineering and Science, Second Edition** Michael Browne, 2009-08-31 Tough Test Questions Missed Lectures Not Enough Time Fortunately for you there's Schaum's Outlines More than 40 million students have trusted Schaum's to help them succeed in the classroom and on exams Schaum's is the key to faster learning and higher grades in every subject Each Outline presents all the essential course information in an easy to follow topic by topic format You also get hundreds of examples solved problems and practice exercises to test your skills This Schaum's Outline gives you Practice problems with full explanations that reinforce knowledge Coverage of the most up to date developments in your course field In depth review of practices and applications Fully compatible with your classroom text Schaum's highlights all the important facts you need to know Use Schaum's to shorten your study time and get your best test scores Schaum's Outlines Problem Solved **Fundamentals of Physics, , Problem Supplement No. 1** Jearl Walker, 2001 This is a supplement to the text Fundamentals of Physics 6th Ed This supplement contains additional sample problems checkpoint style questions organizing questions discussion questions and new exercises and problems *Motion and Time Study* Gerald Nadler, 1955 **Engineering News** , 1910

Engineering News-record , 1910 **Physics for Scientists and Engineers with Modern Physics** Ginsberg, 1994-11

Canadian Engineer , 1914 *Schaum's Outline of Theory and Problems of Elementary Algebra* Barnett Rich, 1993

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Engineering Mechanics R. C. Hibbeler, 1998 New edition of a textbook on the theory and applications of engineering mechanics Topics covered include kinematics and kinetics of particles planar kinematics of a rigid body three dimensional kinematics of a rigid body and vibrations Includes computer problems design projects and countless *Concept-learning Techniques for Motion Control and Robotics* Michel Georges Thouati, 1992 **University Physics** Hugh D. Young, Roger A.

Freedman,2000 This work aims to enable students to develop physical intuition and strong problem solving skills In addition it points out the conceptual and computational pitfalls that commonly plague beginner physics students

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