

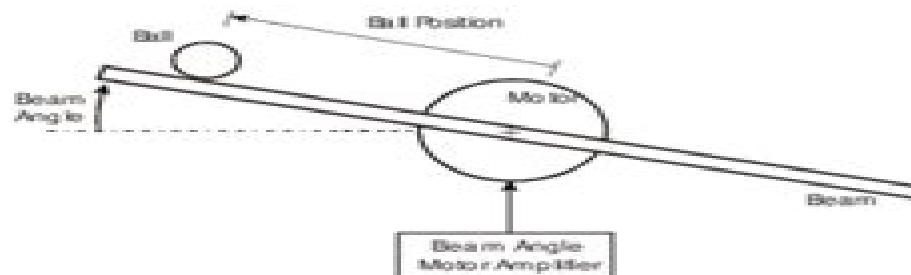
## BALL AND BEAM 1: Basics

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**ABSTRACT:** This is one of a series of white papers on systems modelling, analysis and control, prepared by Control Systems Principles.co.uk to give insights into important principles and processes in control. In control systems there are a number of generic systems and methods which are encountered in all areas of industry and technology. These white papers aim to explain these important systems and methods in straightforward terms. The white papers describe what makes a particular type of system/method important, how it works and then demonstrates how to control it. The control demonstrations are performed using models of real systems that I designed, and which have been developed for manufacture by TQ Education and Training Ltd in their CE range of equipment. This white paper is about a very useful and influential laboratory system for teaching control of unstable systems – the Ball and Beam System.

### 1. What is the Ball and Beam?

The ball and beam system is one of the most enduringly popular and important laboratory models for teaching control systems engineering. The ball and beam system is widely used because it is very simple to understand as a system, and yet the control techniques that can be studied it cover many important classical and modern design methods. It has a very important property – it is open loop unstable.



**Figure 1. The Ball and Beam System.**

The system (shown in figure 1) is very simple – a steel ball rolling on the top of a long beam. The beam is mounted on the output shaft of an electric motor and so the beam can be tilted about its centre axis by applying an electrical control signal to the motor amplifier. The position of the ball on the beam can be measured using a special sensor.

The control job is to automatically regulate the position of the ball on the beam by changing the angle of the beam. This is a difficult control task because the ball does not stay in one place on the beam but moves with an acceleration that is proportional to the tilt of the beam. In control technology the system is open loop unstable because the system output (the ball position) increases without limit for a fixed input (beam angle). Feedback control must be used to keep the ball in a desired position on the beam.

# Ball And Beam 1 Basics Control Systems Principles

**LL Leslie**

A decorative graphic element consisting of a light blue horizontal bar with a rounded right end, and a red circular glow effect positioned behind the bar's end.

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**Computational Intelligence: Theories, Applications and Future Directions - Volume I** Nishchal K. Verma, A. K. Ghosh, 2018-07-31 This book presents selected proceedings of ICCI 2017 discussing theories applications and future directions in the field of computational intelligence CI ICCI 2017 brought together international researchers presenting innovative work on self adaptive systems and methods This volume covers the current state of the field and explores new open research directions The book serves as a guide for readers working to develop and validate real time problems and related applications using computational intelligence It focuses on systems that deal with raw data intelligently generate qualitative information that improves decision making and behave as smart systems making it a valuable resource for researchers and professionals alike

**Computer Aided Design of Multivariable Technological Systems** G. G. Leininger, 2014-05-16 Computer Aided Design of Multivariable Technological Systems covers the proceedings of the Second International Federation of Automatic Control IFAC The book reviews papers that discuss topics about the use of Computer Aided Design CAD in designing multivariable system such as theoretical issues applications and implementations The book tackles several topics relevant to the use of CAD in designing multivariable systems Topics include quasi classical approach to multivariable feedback system designs fuzzy control for multivariable systems root loci with multiple gain parameters multivariable frequency domain stability criteria and computational algorithms for pole assignment in linear multivariable systems The text will be of great use to professionals whose work involves designing and implementing multivariable systems

*Industrial Digital Control Systems* K. Warwick, D. Rees, 1988 Includes Digital signals and systems Digital controllers for process control applications Design of digital controllers Control of time delay systems State space concepts System identification Introduction to discrete optimal control Multivariable control Adaptive control Computer aided design for industrial control systems Reliability and redundancy in microprocessor controllers Software and hardware aspects of industrial controller implementations Application of distributed digital control algorithms to power stations An expert system for process control

*Advances in Control Education 1994* A. Ichikawa, K. Furuta, 2014-05-23 The implementation of effective control systems can help to achieve a wide range of benefits not least in terms of real cost savings Education plays a vital role in ensuring continued success and its importance is well recognized by IFAC with a specifically designated technical committee in this area This invaluable publication brings together the results of international research and experience in the latest control education techniques as presented at the most recent symposium Information on course curricula is presented as well as teachware including software and laboratory experimental apparatus

*Applying Robotics and AI in Pandemics (COVID-19): Detection, Diagnosis and Delivery* Hang Su, John Oyekan, 2022-11-10

**Inverse Dynamic Game Methods for Identification of Cooperative System Behavior** Inga Charaja, Juan Jairo, 2021-07-12 This work addresses inverse dynamic games which generalize the inverse problem of optimal control and where the aim is to

identify cost functions based on observed optimal trajectories The identified cost functions can describe individual behavior in cooperative systems e g human behavior in human machine haptic shared control scenarios

**Non-Linear Differential Equations** Frankie Murray &,2019-11-02 Regarding the matter of differential equations a considerable number of rudimentary books have been composed This book overcomes any issues between rudimentary courses and the examination writing The essential ideas important to contemplate differential equations basic focuses and balance occasional arrangements invariant sets and invariant manifolds are examined Security hypothesis is created beginning with linearisation methods backpedaling to Lyapunov and Poincare The global direct method is then examined To acquire more quantitative data the Poincare Lindstedt method is acquainted with estimated occasional arrangements while in the meantime demonstrating presence by the certain capacity hypothesis The method of averaging is presented as a general estimation standardization method The last four sections acquaint the peruser with unwinding motions bifurcation hypothesis focus manifolds disarray in mappings and differential equations Hamiltonian frameworks repeat invariant tori intermittent arrangements The book displays the subject material from both the subjective and the quantitative perspective There are numerous cases to delineate the hypothesis and the peruser ought to have the capacity to begin doing research in the wake of concentrate this book

*Zhang-Gradient Control* Yunong Zhang,Binbin Qiu,Xiaodong Li,2020-11-24 This book introduces readers to using the simple but effective Zhang gradient ZG method to solve tracking control problems concerning various nonlinear systems while also highlighting the applications of the ZG method to tracking control for practical systems e g an inverted pendulum on a cart IPC system and a two wheeled mobile robot showing its potential applications In addition to detailed theoretical analyses of ZG controllers the book presents a wealth of computer simulations to demonstrate the feasibility and efficacy of the controllers discussed as well as the method itself More importantly the superiority of ZG controllers in overcoming the division by zero DBZ problem is also illustrated Given its scope and format the book is well suited for undergraduate and graduate students as well as academic and industrial researchers in the fields of neural dynamics neural networks nonlinear control computer mathematics time varying problem solving modeling and simulation analog hardware and robotics

**Proton and Carbon Ion Therapy** C-M Charlie Ma,Tony Lomax,2012-10-09 Proton and Carbon Ion Therapy is an up to date guide to using proton and carbon ion therapy in modern cancer treatment The book covers the physics and radiobiology basics of proton and ion beams dosimetry methods and radiation measurements and treatment delivery systems It gives practical guidance on patient setup target localization and treatment planning for clinical proton and carbon ion therapy The text also offers detailed reports on the treatment of pediatric cancers lymphomas and various other cancers After an overview the book focuses on the fundamental aspects of proton and carbon ion therapy equipment including accelerators gantries and delivery systems It then discusses dosimetry biology imaging and treatment planning basics and provides clinical guidelines on the use of proton and carbon ion therapy for the treatment of specific

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