Mechatronics Systems

Mechatronics is that branch of engineering that deals with combined mechanical, electronic and software systems.

The elements of mechatronics systems include sensors, actuators, microcontrollers (or microprocessors) and real-time control software.

Design Process

- **The Need:** The design process begins with a need from, let us say, a customer or client. This may be identified by market research being used to establish the needs of potential customers.

- **Analysis of the Problem:** The first stage in developing a design is to find the true nature of the problem. That means analyzing it. This is a critical stage since not defining the problem accurately may lead to wasted time on designs and accordingly the need will not be fulfilled.

- **Preparation of a Specification:** After analyzing the problem a specification of the requirements can be prepared. This will state the problem, will state any constraints placed on the solution, and will set up the criteria which may be used to judge the quality of the design. In stating the problem, all the functions required of the design with all features should be specified. Accordingly, there may be statements of mass, dimensions, types and range of motion required, accuracy, input and output requirements of elements, interfaces, power requirements, operating environment, relevant standards and codes of practice, etc.

- **Possible Solutions:** This is often called conceptual stage. Outline solutions are prepared which are worked out in sufficient detail to indicate the means of obtaining each of the required functions, e.g., approximate sizes, shapes, materials and cost. It also means what has been done before for similar problems.

- **Selection of Suitable Solution:** The various solutions are evaluated and the most appropriate one should be selected.

- **Production of a Detailed Design:** The details of the selected design has to be worked out. Modeling and simulation are a great help. This might require the production of prototype or mock-ups in order to determine the optimum details of a design.

- **Production of Working Drawings:** The selected design is then translated into working drawings, circuit diagrams, so that the item can be manufactured.

Features of Mechatronic Design

- Engineering design is a complex process involving interaction between many skills and disciplines.

- The basis of the mechatronics approach lies in the inclusion of the disciplines of electronics, computer technology, and control engineering.

- An example is the temperature control of a domestic central heating system which traditionally relies on the bimetallic thermostat in a closed-loop control system. The bending of the bimetallic strip changes as the temperature changes and it operates as on/off switch for the heating systems. A mechatronics solution to the problem might be to use a microprocessor-controlled system employing a thermodiode as the sensor. Such a system has many advantages over the bimetallic one including accuracy and flexibility.

Embedded Systems

- Microprocessors and microcontrollers are often “embedded” in a system so that the control may be exercised.

- An example is the washing machine!

- An embedded system is used for a microprocessor-based system that is designed to control a function or range of functions and is not aimed to be programmed by the system user.

- The programming has been done by the manufacturer and has been “burnt” into the memory system and can not be changed by the user.

Design Parameters

- **Electrical**
  - Resistivity/conductivity
  - Dielectric constant
  - Dielectric strength
  - Dielectric loss
  - Magnetic permeability and saturation
  - Eddy current loss
  - Hysteresis loss
  - Skin effect
  - Electromagnetic forces
  - Electrostatic voltages
  - Corrosion from leakage currents

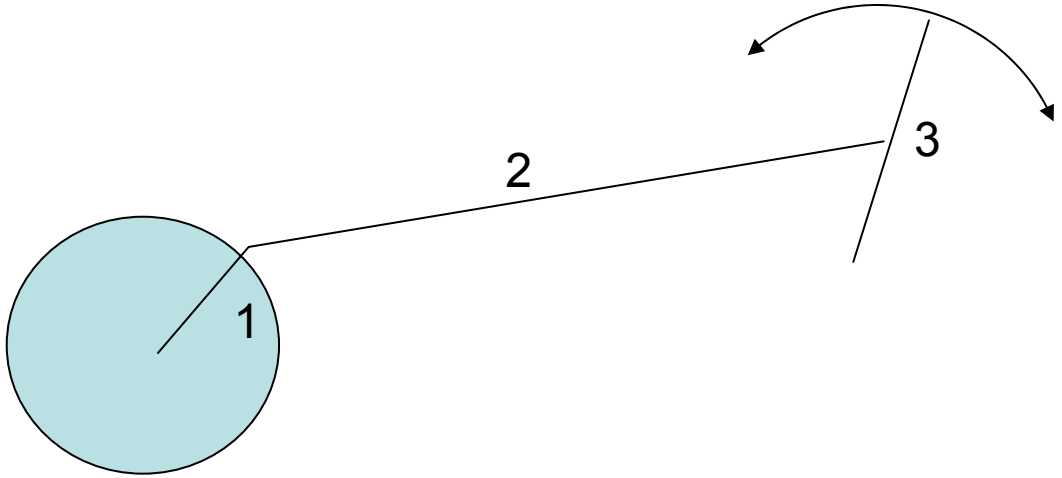
- **Mechanical**
  - Dimensions and shape
  - Stress distribution
  - Strength
  - Stiffness/rigidity
  - Weight and distribution
  - Hardness/wear resistance
  - Toughness
  - Friction/lubricity
  - Damping
  - Creep
  - Fatigue

- **Chemical**
  - Chemical resistance and corrosion
  - Chemical harmfulness and pollution
  - Adhesive bondability
  - Porosity
  - Fading

- **Biological**
  - Toxicity
  - Carcinogenesis
  - Fungus resistance
  - Other microorganism resistance.

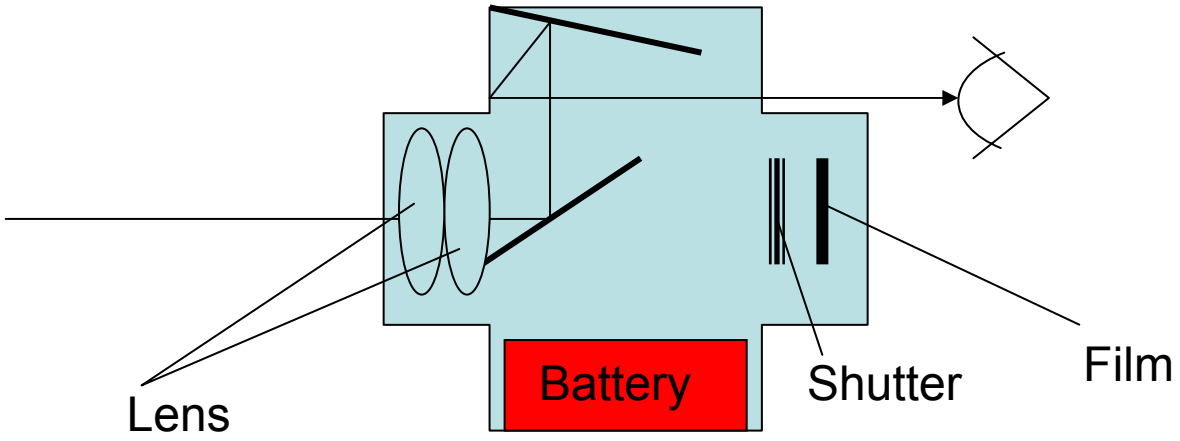
Case Study 1

Consider a device that oscillates an arm back and forth in an arc like a windscreen wiper. A mechanical solution is shown in the following Figure. Rotation of arm 1 causes arm 2 to impart an oscillatory motion to arm 3. An alternative solution is to use a stepper motor. Draw the circuit for interfacing a stepper motor and derive the transfer function between the input voltage and the resulting angular displacement.



Case Study 2

The Figure below shows the basic features of a Camera. The camera is automatic, auto-focus, and reflex. The camera has interchangeable lenses. There is a main controller in the camera body and another microcontroller in the lens housing, the two communicating with each other when a lens is attached to the camera body. Draw the block diagram of the electronic system.



Case Study 3

All modern cars contain many electronic control systems involving microcontrollers. One important feature is the engine control system. Its aim is to ensure that the engine is operating at its optimum settings. The system consists of sensors supplying, after suitable signal conditioning, the input signals to the microcontroller and it provides output signals via drives to actuate actuators. Draw a block diagram of the engine management systems showing the required sensors.

- Research the anti-lock braking system used in cars and describe the principle of its operation.
- Research the control area network (CAN) protocol used with cars.

Case Study 4

Describe a permanent-magnet DC motor and draw its equivalent circuit.

Derive the mathematical modeling (transient dynamics) of a permanent-magnet DC motor. What are the applications of permanent-magnet DC motors in mechatronic systems?

- What are the ways of controlling a permanent-magnet DC motors?
- With the aid of a block diagram, derive the mathematical modeling that map the augmented circuitry and torsional-mechanical dynamics.