AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
MECHATRONICS ENGINEERING DEPARTMENT
Mechatronics and Robotics Engineering Program

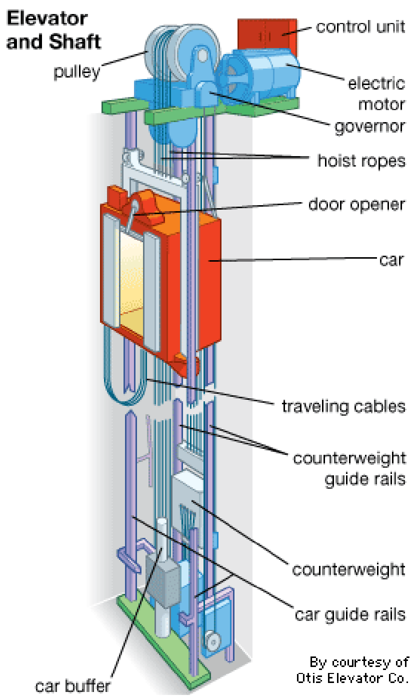
Spring, 2026

MCT333/ MCT344: Mechatronic Systems Design

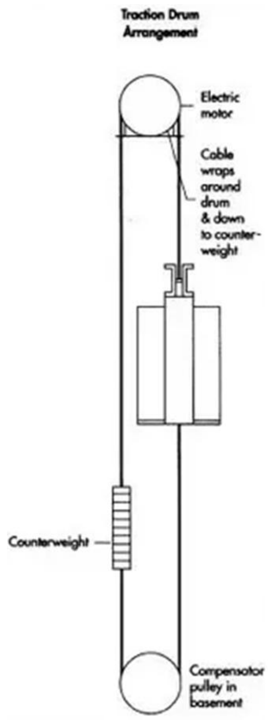
Sheet 1: Mechatronic Systems Design Philosophy

Support your answer with sketches and diagrams as much as possible.

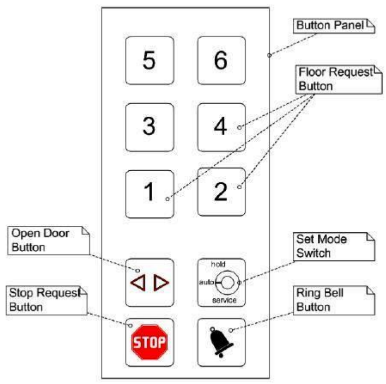
1) We use elevators daily in our daily living transfers within buildings between floors. Elevators, as shown in the figure 1, present examples of mechatronic systems. They have many sensors to detect the position, speed, …etc. of the elevator car, as well as any calls registered by the passengers. Also, It has many actuators, mechanical parts, mechanisms, electrical and electronics, control algorithms, ..etc.. Safety is also essential in these systems as they carry human beings and they life are important.



Detailed Drawing of Elevator



Simplied schematic



The elevators button panel

Elevator button panel

Figure 1: Elevator

In the light of the previous paragraph and based on your daily usage of the elevator:

a. Apply mechatronic system configuration, and identify the mechatronic system components in the elevator and their relation within the mechatronic system configuration. Use sketches and diagrams to support your answer.
b. In the mechatronic design process, the first step is to identify the need and find the list of product requirements. Based on your usage of the elevator as a customer and also as an

engineer, list at least 4 requirements that you need to consider when you design and control an elevator.

c. Draw the Function Structure Diagrams (FSD) of the elevator and show the material, energy, and information flows to perform its operation function
d. Explain how you can apply the TRIZ principles for brainstorming to propose design solutions for this elevator
e. Elevators have many mechanisms to transfer and change type of movement, choose/suggest two mechanisms used in the elevator and explain their function, mobility, and degrees of freedom. Use sketches and diagrams to support your answer.
f. If the elevator pulley diameter is 30cm which is coupled to a motor through gearbox with reduction ratio 1:30. If the maximum motor speed is 1500 rpm, what is the maximum linear speed in m/s of the elevator car?
g. What are the safety considerations can be considered during the elevator control and how can mechatronic approach be applied to implement the safety considerations? Suggest at least one of safety example can be applied in the elevator.
h. If a microcontroller (Arduino for example) was used to control the elevator and only the digital inputs/outputs be considered, draw a simplified flow chart and also its simplified Arduino code that show an elevator transferring from level 0 to level 1 when you choose level 1 button in the elevator button panel.

2) You are tasked with designing, developing, and implementing a bio-inspired legged robot using a mechatronic design process.
   a. Identify the key *system needs* and derive clear *system engineering requirements* (functional, performance, environmental, and safety).
   b. Apply the VDI 2206 design methodology to outline the main development phases and key deliverables for this robot.
   c. Use TRIZ principles to generate and justify concepts for the robot's design and actuation mechanism (overall robot level).
   d. Then, focus on one leg: present a detailed concept/design of a single leg that can adapt and interact effectively with changing terrain and environmental conditions.

   Support your answer with sketches wherever possible.

3) For each of the following mechatronic products: (a) coffee roaster machine, (b) dishwasher, (c) vending machine, do the following:
   a. Specify the inputs and outputs (material, energy, and information).
   b. State the key design specifications.
   c. Draw a detailed Functional Structure Diagram (FSD) showing the material, energy, and information flows.

4) A desktop fused-deposition modeling (FDM) 3D printer builds a plastic part layer-by-layer from filament. The system includes motion axes, an extruder, a heated bed, sensors, firmware, user interface, …etc.
   a. Identify the main inputs and outputs (Material, Energy, Signal/information).
   b. Decompose the system into at least 5-7 functions.
   c. Draw a Functional Structure Diagram (FSD) showing functions and flows.
   d. For each function, propose at least one feasible solution element. You may use TRIZ principles to support brainstorming and idea generation.

5) You aim to increase FDM 3D-printing speed to reduce build time. However, higher speed can introduce vibration and extrusion/flow errors, leading to poorer dimensional accuracy and surface quality. Propose engineering solutions that enable higher printing speed while minimizing vibration and maintaining print quality. As solution guide, your answer may include or others:
   - Mechanical measures (e.g., frame stiffness, motion system design, resonance reduction, ..etc.), and
   - Control/process measures (e.g., input shaping, acceleration/jerk tuning, motion trajectory control, flow compensation, cooling, etc.).

   You may reference strategies used in fast FDM printers (e.g., Bambu Lab or other high-speed printing systems) as inspiration.

   You are required to apply TRIZ:
   a. Write the contradiction in one sentence using the format: *"If we improve X, then Y gets worse."*
   b. Select suitable TRIZ engineering parameters (from the 39 parameters) for: the parameter to be improved, and the parameter that worsens.
   c. Using the TRIZ contradiction matrix table, identify 3–5 inventive principles (from the 40 principles) that could resolve the contradiction.
   d. Propose 2–4 concept-level design ideas based on the selected principles, and briefly explain how each idea reduces vibration/flow errors while enabling higher speed.

6) You are tasked with designing and developing a myoelectric prosthetic hand for daily living activities, while balancing grip force, device weight, battery endurance, and user comfort. Your tasks include:
   a. Identify the main user needs and translate them into 8–12 clear engineering requirements.
   b. Define quantitative design specifications for grip force, response time, and overall weight.
   c. Develop a Functional Structure Diagram (FSD) that maps the system from EMG acquisition → signal processing and control → motor actuation → grasp output, including feedback sensing and control loops.
   d. Apply TRIZ to address the contradiction: high grip force vs. low weight (state the contradiction and propose concept-level solutions).
   e. Outline a development plan aligned with VDI 2206, covering system design, domain-specific design, and integration and testing.

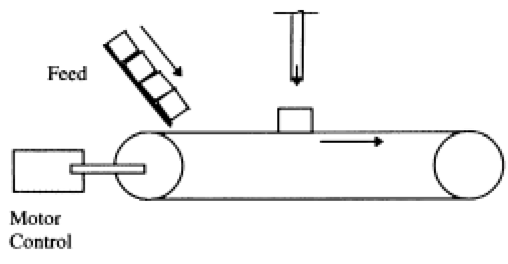
7) You are tasked with designing an indoor autonomous mobile robot to deliver blood samples/specimens inside a hospital (navigation through corridors and using elevators to move between floors within the same building). The design must emphasize patient/staff safety, traceability, hygiene/infection control, …etc.
   a. Identify the primary mission/need and the main constraints (hospital workflow, infection-control requirements, building layout, elevator usage, …etc.).
   b. Derive 10–15 clear system requirements (functional, performance, safety, operational, …etc.).
   c. Define quantitative safety specifications, such as maximum speed in different zones, stopping distance, obstacle-detection range, warning/alert signals, and emergency-stop response.
   d. Develop a Functional Structure Diagram (FSD) that includes: perception/sensing, localization, path planning, motion control, specimen handling, docking/charging, and user communication/traceability.

e. Apply a VDI 2206-based verification and validation plan, including unit tests, integration tests, and system-level validation in a hospital-like environment.

8) Automatic sliding doors are widely used in hospitals, malls, and airports to provide hands-free access and improve accessibility.
   a. Describe the mechatronic system configuration of an automatic sliding door, and classify its components into: mechanical, electrical/power, sensing, control, and software/HMI.
   b. State six system requirements, considering accessibility, safety, energy consumption, and reliability.
   c. Draw a Functional Structure Diagram (FSD) showing the material, energy, and information flows.
   d. Identify two potential safety hazards and explain how a mechatronic safety approach (sensing + control + mechanical design) can mitigate each hazard.
   e. Apply VDI 2206, briefly describe the system design phase and the domain-specific design phases for this product.

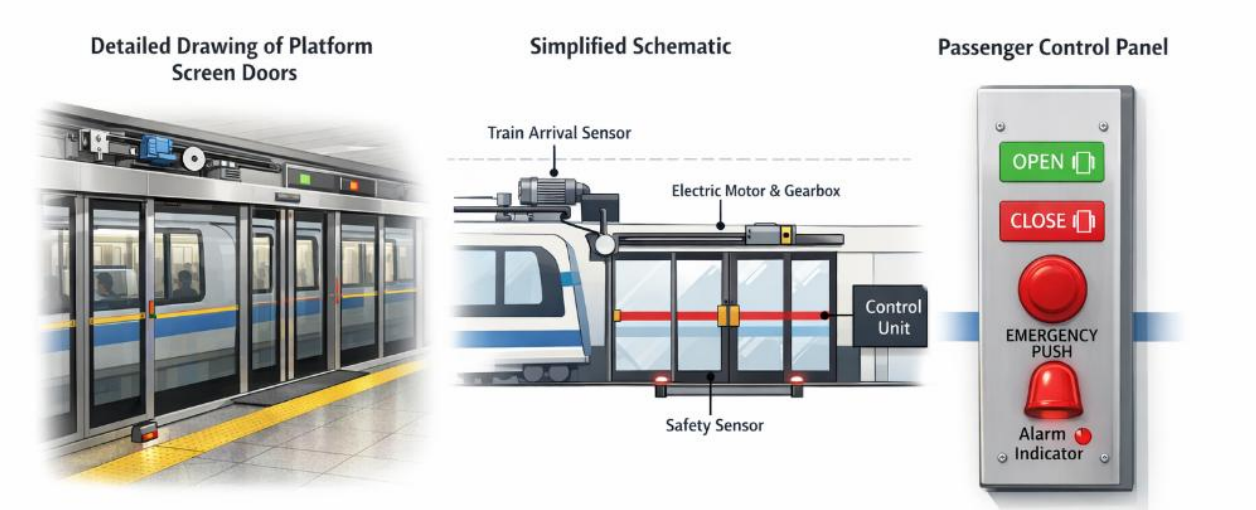
9) An electric scooter should be lightweight, and it must also provide a long driving range. Based on this description:
   a. Write the engineering contradiction in a clear sentence (e.g., *"If we improve X, then Y gets worse."*).
   b. Identify the corresponding TRIZ engineering parameters (from the 39 parameters) for the improved and worsened aspects.
   c. Using the TRIZ contradiction matrix, select three inventive principles that could help resolve the contradiction.
   d. Propose concept-level solution ideas based on the selected principles, and briefly explain how each concept affects weight and range**.**

10) Sensors are used to monitor the amount of solid or liquid filled in containers, and a conveyor mechanism transports the containers through the process shown in the figure below. Using the VDI 2206 mechatronic design approach, design a complete system for this application. Your answer should be according to VDI 2206 steps and also cover: the overall system architecture, Identify suitable sensor types, the system operating sequence, interface the sensors and actuators, …etc. Provide sketches/diagrams where appropriate.



11) Platform Screen Doors (PSDs) are widely used in modern metro and railway stations in some countries to improve passenger safety and control access to the tracks. A typical PSD system (see the provided figure below) consists of multiple sliding doors installed along the platform edge. These doors open and close automatically in synchronization with the arriving train doors. The system integrates mechanical structures, electric drives, sensors (train presence +

door position), control units, communication interfaces, and safety mechanisms. Because of high passenger density and interaction with moving trains, safety and reliability are critical.



a. Using the mechatronic system configuration concept, identify and classify the PSD system components (mechanical, electrical/power, sensing, control, communication, and safety), and explain how they interact within the overall mechatronic system. Use sketches/block diagrams to support your answer.
b. In the mechatronic design process, the first step is identifying the need and defining product requirements. Based on your experience as a passenger and as an engineer, list at least 8 requirements that should be considered when designing and controlling a PSD system.
c. Draw the Functional Structure Diagram (FSD) of the PSD system, showing the required material, energy, and information flows to perform its main operation (open/close synchronized with train operation).
d. PSD systems use mechanisms to generate and guide motion. Choose two mechanisms used in PSDs (e.g., belt–pulley drive, rack-and-pinion, lead screw, linear guide system, etc.). For each mechanism, describe its function, mobility, and degrees of freedom (DOF). Support your answer with sketches.
e. Each sliding door is driven by an electric motor coupled to a gearbox and a pulley mechanism. If the pulley diameter is 25 cm, the gearbox reduction ratio is 1:20, and the maximum motor speed is 1200 rpm, calculate the maximum linear speed (m/s) of the sliding door panel. State any assumptions clearly.
f. Safety is essential in PSD systems. Describe key control-related safety considerations (e.g., obstacle detection, fail-safe operation, emergency stop, fault detection, redundancy, etc.). Explain how a mechatronic safety approach (sensing + control + mechanical design) can implement these considerations, and suggest at least one safety function for the system.
g. If a microcontroller (e.g., Arduino) is used to control one PSD door unit, and only digital inputs/outputs are available, do the following:
    i. Draw a simplified flowchart for the door control logic.
    ii. Write simplified Arduino-style code to open and close the door based on:
        - a train arrival signal, and
        - a departure command.

    Include reasonable digital signals such as: door-open limit switch, door-closed limit switch, obstruction/emergency input, motor open/close outputs.