# SNS College of Engineering

Department of Mechanical & Mechatronics Engineering (AM)

19MO602 – Design Mechatronics System

**Question Bank**

## PART-A

1. **Define Mechatronic Systems.**

   The system changed from electro mechanical systems with discrete electrical mechanical parts to integrated electronic -mechanical systems with sensors, actuators and digital microelectronics. These integrated systems are called mechatronic systems.

2. **Define System Modeling.**

   Modeling is the process of representing the behavior of a real system by a collection of mathematical equations and logic.

3. **Write the important life cycle factors in mechatronic system.**

   i) Delivery,
   ii) Reliability
   iii) Maintainability,
   iv) Serviceability,
   v) Upgradeability and
   vi) Disposability.

4. **What are various risks involved in designing safety of Mechatronics systems?**

   Operator safety and Machine safety are the two safety systems involved in Mechatronics system.

5. **What is transfer function?**

   It is defined as the relationship between the input parameter and output parameter.

6. **Define simulation.**

   Simulation is the process of solving the model and is performed on a computer. Although simulations can be performed on analog computers, it is far more common to perform them on digital computers. The process of simulation can be divided into three sections: initialization, iteration and termination.

7. **Write the main area of operator risk.**

   i) Trapping,

ii) Entanglement,
iii) Impact and
iv) Ejection.

8. **Write the applications of Mechatronics systems?**

i) Fuzzy based washing machine,
ii) Autofocus Camera,
iii) Engine management system and
iv) Autonomous Robots.

9. **What is modified analog approach?**

Analog approach includes the state graphs, multi body diagrams, circuit diagrams to represent a model. The implementation of the digital control systems replaces the electric circuits and prototype for the mechanics system. This technique is called modified analog approach.

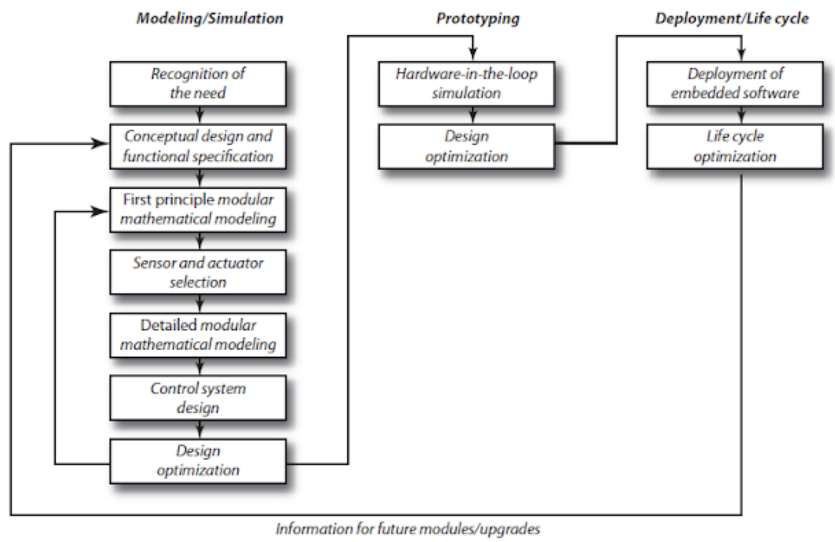
10. **What are the key elements of Mechatronic Systems**.

i) Physical System Modeling
ii) Sensors and Actuators
iii) Signals and Systems
iv) Computers and Logic Systems and Software and Data Acquisition

**PART-B**

1. **What are the steps involved in design of mechatronic system?**

The mechatronic design process consists of three phases: modeling and simulation, prototyping, and deployment. All modeling, whether based on first principles (basic equations) or the more detailed physics, should be modular in structure. A first principle model is a simple model which captures some of the fundamental behavior of a subsystem. A detailed model is an extension of the first principle model providing more function and accuracy than the first level model. Connecting the modules (or blocks) together may create complex models. Each block represents a subsystem, which corresponds to some physically or functionally realizable operations, and can be encapsulated into a block with input/output limited to input signals, parameters, and output signals. Of course, this limitation may not always be possible or desirable; however, its use will produce modular subsystem blocks which easily can be maintained, exercised independently, substituted for one another (first principle blocks substituted for detailed blocks and vice versa), and reused in other applications.




Because of their modularity, mechatronics systems are well suited for applications that require reconfiguration. Such products can be reconfigured either during the design stage by substituting various subsystem modules or during the life span of the product. Since many of the steps in the mechatronics design process rely on computer-based tasks (such as information fusion, management, and design testing), an efficient computer-aided prototyping environment is essential.

The mechatronic design methodology is not only concerned with producing high-quality products but with maintaining them as well—an area referred to as life cycle design. Several important life cycle factors are indicated.

• Delivery: Time, cost, and medium.
• Reliability: Failure rate, materials, and tolerances.
• Maintainability: Modular design.
• Serviceability: On board diagnostics, prognostics, and modular design.
• Upgradeability: Future compatibility with current designs.
• Disposability: Recycling and disposal of hazardous materials.

We will not dwell on life cycle factors except to point out that the conventional design for life cycle approach begins with a product after it has been designed and manufactured. In the mechatronic design approach, life cycle factors are included during the product design stages, resulting in products which are designed from conception to retirement.

**2. Compare the traditional design approach with mechatronic design approach**

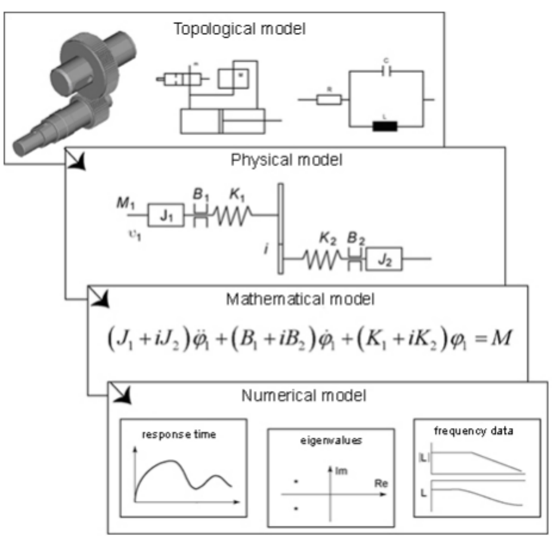
| S.No | Traditional Approach | Mechatronics Approach |
|---|---|---|
| 1. | Bulky system | Compact |
| 2. | It is a complex process involving interactions between many skills and disciplines. | It is the basic of integration of various emerging technology with mechanical engineering. |
| 3. | The control is accomplished by manually. | A microprocessor is used a controller by programming it. |
| 4. | Complex mechanisms | Simplified mechanism may transferred to the software through programs. |
| 5. | Non-adjustable movement cycles | Programmed movements. |
| 6. | Constant speed drives | Variable speed drives |
| 7. | Mechanical Synchronization | Electronic Synchronization |
| 8. | Rigid heavy structures | Lighter Structures. |
| 9. | Accuracy determined by tolerance of mechanism | Accuracy achieved by feedback |
| 10. | Flexibility is less | Flexibility is more. |
| 11. | Less accurate | More accurate. |
| 12. | It consists of more components and moving parts. | It involves less components and moving parts |
| 13. | Less wst | High cost. |

**3. Explain the various modelling techniques.**

A required quality of the model is fundamentally dependent on the problem to be considered. Therefore, before modelling is commenced, there should be clarity concerning the development task. For new development tasks, different modelling approaches are to be chosen compared to those required for further development or optimization of existing products. Depending on the question to be answered, the depth of modelling varies with regard to the consideration for specific physical effects.

**Physical model:** Starting from the topological description, a physical model is created. This is defined by system-adapted variables, such as for example masses and lengths in the case of mechanical systems or resistances and inductances in the case of electrical systems. In the case of mechanical elements, e.g. the number and connections of rigid bodies, definition of flexible bodies, bearing friction and clearance or mass distributions are stipulated. With hydraulic systems, the physical model comprises e.g. such components as hydraulic chambers and valves, but also the replication of physical effects, such as leakages, frictions or hysteresis. The physical model describes the system properties in a domain-specific form.

**Mathematical model:** The mathematical model forms the basis of behavioral description of the system. For this purpose, the physical model is transferred in an abstract, system independent representation and the physical properties of the model described above are formulated with the aid of mathematical descriptions. Differences in the depth of modelling may arise here for example due to more faithfully detailed hydraulic line models, more detailed friction models, due to more sophisticated bending evaluations in the calculation of elastic structures or due to consideration of nonlinearities instead of linearization. The mathematical model integrates different domain-specific model representations.

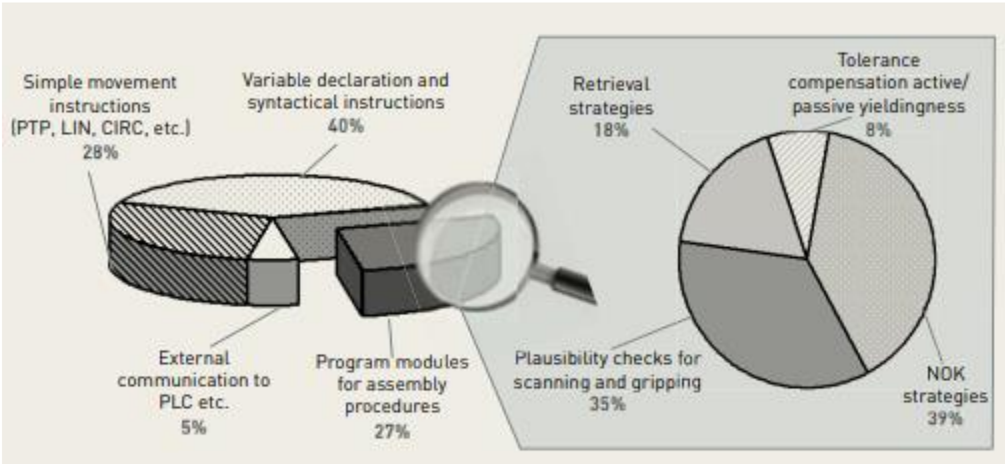



**Numerical model:** The mathematical model is then prepared in such a way that it can be algorithmically handled and subjected to a computer-aided process, for example simulation. The numerical model depends very strongly on the depth of modelling realized, on the solving method used and on the mathematical model (in particular with regard to nonlinearities). The numerical model is provided with concrete numerical values (parameterized). These numerical values are possibly determined by an identification of the real system (if present) (cf. procedure for modelling). Figure 7.11 shows procedural steps for modelling that are typically to be taken and under some circumstances must be iteratively repeated.

**4. What is meant by plausibility test? Explain how its performed.**

The robots execute tasks such as work piece positioning, material handling, assembling and screwing. The analysis is based on 99415 lines of code. The robot programs can be divided into the following groups: Simple movement instructions (point to point, linear, circular etc.) Variable

declaration and syntactical instructions External communication to PLC etc. Program modules for assembly procedures For executing assembly tasks with high process reliability, several program modules such as retrieval strategies, active and passive tolerance compensation, Not-Okay (NOK) strategies as well as plausibility checks are implemented. The whole structure of robot programs – divided into different modules for assembly tasks – is illustrated in Figure 4. The coherent sectors of the pie chart (73%) can already be developed offline with today‘s simulation environments. The remaining 27% are essential program modules for the execution of assembly tasks and offline programming is not possible without accomplishing these program modules. VIPD enables the robot programmers to create and validate program modules such as retrieval strategies, active and passive tolerance compensation, NOK strategies as well as plausibility checks for scanning and gripping procedures. In this context, a retrieval strategy is defined as a cyclic sensor monitoring for the test of a condition during a given trajectory. With fulfilled condition, it emits target coordinates for dynamical robot positioning. Tolerance compensation with yieldingness leads to a guaranteed force controlled joining of parts with position and form tolerances. NOK strategies are alternative program sequences for the case of incorrect positioning, gripping or joining states. The sequences contain all procedures to restore an admissible process status. Plausibility checks are implemented to prevent inadmissible and dangerous states while gripping or moving, which can damage work pieces, operational resources or the robot itself. Based on that knowledge, the following key requirements for the simulation environment are defined: 1. Usage of the original robot controller (RC) 2. Plausible reactions of the robotic peripherals (robot trajectory and signal behavior) 3. Interaction with the simulation environment.




**5. What are the applications of mechatronic system? Explain with example**

Mechatronics applies all the basic principles related to machines, electronics, and informatics combined and synergized into one. Generally, combining all these elements is created to create a new technology that is useful for humans.

The application of mechatronics is usually not far from things such as machinery, electronics, and informatics. It's just that it was created more complex to fulfil a certain function. One of the characteristics of the application of mechatronics is that it is multipurpose.

As we know, of course, all the fields mentioned will be encountered by humans around them every day. Therefore, mechatronics is considered one of the most important types of science, and its impact can be felt directly in daily human life.

Hence, mastering the science of mechatronics means that we can also become useful people for the lives of others through various mechatronic devices that we create for human life so that they can be used and benefited.

**Examples of Mechatronic Application Techniques That are Beneficial to Human Life**

Studying mechatronic engineering can have very good long-term prospects because graduates from these fields of study are very much sought after by companies where mechatronics knowledge will be indispensable in a company for various purposes. This is because there are still very few people who even understand what mechatronics is. Sometimes its application in everyday life is not given much attention even though the application of mechatronics is very important for human life; here are some examples of the application of mechatronics technology.

1. **ABS ( Anti-lock Braking System )**

The first mechatronics applications are usually found in the automotive world, where the braking system is vital in the automotive sector. Manufacturers must pay close attention to the braking system in their products.

This is what ultimately led to the creation of ABS or anti-lock braking system; ABS itself is one of the applications of mechatronics where ABS is a system integrated into a vehicle that helps the driver stay safe while driving, even on slippery roads or when sending a premature delivery.

The vehicle's wheels will not be locked even if the driver brakes suddenly and extremely with the ABS technology. With the ABS technology, you will be safer when driving.

2. **ESP ( Electronic Stability Program )**

Along with the development of increasingly sophisticated technology, one of the impacts is the automotive world. Each automotive product is more comfortable and safer, along with various advanced technologies to support these automotive products. One of the features that use the mechatronic principle is or electronic stability control. That is a technology integrated with a computerized system that has an important function to improve security in terms of car control through sensors that can detect and minimize slippage. Therefore, this program always ensures that the vehicle is in good control.

3. **ABC ( Active Body Control )**

ABC or active body control is an advanced suspension technology system that consists of various components integrated into a single system that makes the technology operable. The working system of this technology can dampen the car in all road conditions. Whether it's a good road or an extreme road due to damage or steepness, this system will increase the comfort of the driver and passengers by controlling the springs and damping each wheel of the vehicle. The performance of this ABC system has been integrated by a computer so that it can work automatically; for example, this system will use hydraulics to reduce enormous pressures and use conventional shock absorbers to overcome small pressures.

4. **Motor Management System**

The next application of mechatronics is the motor management system, an integrated system that controls and controls the entire performance of the machine and is controlled by a single device called an electronic control unit or contents.

As a result, the machine can be controlled and always in the best performance because the data on the machine is computerized very sophisticatedly. In this technology, all machine components utilize sensors as inputs which will then be processed in the electronic control unit.

5. **Comfort in Turbulence System**

Turbulence is one of the most common terms encountered in the aviation sector and is already familiar. Turbulence itself should not be ignored and underestimated because it can cause various dangerous events.

One of the positive impacts of mechatronic technology is the creation of comfort in turbulence system technology, where the system functions to minimize the impact of turbulence which can increase the comfort of wrong passengers.

6. **Robojet Manipulator**

People do not widely know this tool, but its function is very important for human life. This robot manipulator is a piece of heavy equipment usually used to dig tunnel systems where the working mechanism is regulated and driven using a hydraulic system. The manipulator robot can scan the profile of the tunnel that you want to excavate.

Furthermore, it can calculate the exact direction and the concentrated liquid to be sprayed accurately because this tool requires a paint sprayer that has a function to accurately attach the concentrated liquid to the part to be excavated.

**6. Explain the bottom-up design concept and compare this with top-down design concept. State its advantages & disadvantages.**

In **System Design**, there are two types of approaches followed namely, the **Bottom-Up Model** and the **Top-Down Model**.

- The bottom-up model is one in which the different parts of a system are designed and developed and then all these parts are connected together as a single unit.
- On the other hand, the top-down model is one in which the whole system is decomposed into smaller sub-components, then each of these parts are designed and developed till the completed system is designed.

**Bottom-Up Model** is a system design approach where the parts of a system are defined in details. Once these parts are designed and developed, then these parts or components are linked together to prepare a bigger component. This approach is repeated until the complete system is built. The advantage of Bottom-Up Model is in making decisions at very low level and to decide the re-usability of components.

**Top-Down Model** is a system design approach where the design starts from the system as a whole. The complete system is then divided into smaller sub-applications with more details. Each part again goes through the top-down approach till the complete system is designed with all the minute details. Top-Down approach is also termed as breaking a bigger problem into smaller problems and solving them individually in recursive manner.

Difference between Bottom-Up Model and Top-Down Model

The following are the important differences between Bottom-Up Model and Top-Down Model −

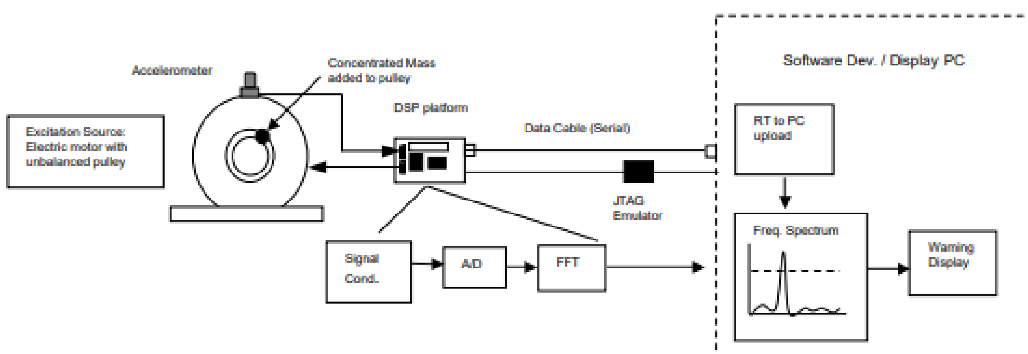
| Key | Bottom-Up Model | Top-Down Model |
|---|---|---|
| Focus | In Bottom-Up Model, the focus is on identifying and resolving smallest problems and then integrating them together to solve the bigger problem. | In Top-down Model, the focus is on breaking the bigger problem into smaller one and then repeat the process with each problem. |
| Language | Bottom-Up Model is mainly used by object oriented programming languages like **Java**, **C++**, etc. | Top-Down Model is followed by structural programming languages like **C**, **Fortran**, etc. |
| Redundancy | Bottom-Up model is better suited as it ensures minimum data redundancy and focus is on re-usability. | Top-down model has high ratio of redundancy as the size of project increases. |
| Interaction | Bottom-Up model have high interactivity between various modules. | Top-down model has tight coupling issues and low interactivity between various modules. |
| Approach | Bottom-up model is based on composition approach. | Top-down model is based on decomposition approach. |
| Issues | In Bottom-Up, sometimes it is difficult to identify overall functionality of system in initial stages. | In Top-Down, it may not be possible to break the problem into set of smaller problems. |

Conclusion

The most significant difference between the two types of models is that the bottom-up model is based on the composition approach, while the top-down model is based on the decomposition approach.

7. **Compare hardware in loop simulation and control prototyping processes in the design of Mechatronics system.**

This embedded DSP based Hardware in the Loop setup consist of the following components: 1) Electric motor used as excitation source with balanced/unbalanced pulley placed on its shaft. 2) Uniaxial accelerometer to measure radial acceleration component. 3) DSP platform used for conditioning of signal from accelerometer, Analog to Digital conversion of signal, FFT and limit detect algorithm processing. 4) Software development and display PC for frequency spectrum display and warning display. Algorithm development and debugging is done on the PC using block diagram simulation
software capable of generating C code. This makes it a language neutral process and a resulting code that is portable. Several block diagram programming tools for DSP exist such as Mat lab Simulink and Hypersignal Ride. These are programs capable of simulating algorithms in a graphical user interface (GUI) environment using a host of software building blocks. The program is then compiled, converted into assembly code and downloaded to the DSP platform for execution. With the DSP being used as the processor, the PC is then used only as a means of visual display for results.




For this setup, two test cases are considered: One with a balanced pulley added to the electric motor shaft and the other with an unbalanced pulley added to the shaft. The amplitude vs. frequency response was recorded for the balanced and unbalanced conditions. For the balanced case, a peak amplitude of 14.1 Db is observed at 30 Hz. Whereas for the unbalanced case a peak amplitude of 37.6 Db is present at 30 Hz. Thus, a threshold value can be set such that a limit detect algorithm can determine the unbalance condition and provide the appropriate feedback control signal.

DSP based Hardware-in-the-Loop testing using block diagram simulation software can be made to provide real-time control with minimum expertise in embedded processors. Hardware-in-the loop simulation is a cost-effective method to perform system tests in a virtual environment. Most of the environment components are replaced by mathematical models while the components to be tested are inserted into the closed loop. As such, rapid prototyping and hardware-in-the-loop simulation are an integral part of today's product development process. So the use PC based modeling simulation along with Rapid Control Prototyping and Hardware-in-the-Loop simulation demonstrates a level of interaction with the modeling of a system that is not possible when code is directly ported to the final target platform.

**8. Discuss the stages of Mechatronic design processes.**

Since many of the steps in the mechatronic design processes rely on computer-based tasks such as information. Fusion, management, and design testing, and efficient computer-aided prototyping environment is essential. Some of the important features of such an environment are listed and described below

•Modeling: Block diagram or visual interface for creating intuitively understandable behavioral models of physical or abstract phenomena. The ability to encapsulate complexity and maintain several levels of sub model complexity is useful.

•Simulation: Numerical methods for solving models containing differential, discrete, hybrid, partial, and implicit nonlinear se well as linear equations. Must have a lock for real-time operation and be capable of executing faster than real time.

• Project Management: Database for maintaining project information and sub models for eventual reuse.

• Design: Numerical methods for constrained optimization of performance functions based on model parameters and signals. Monte Carlo type capability is also desirable.

• Analysis: Numerical methods for frequency domain, time domain, and complex domain design.

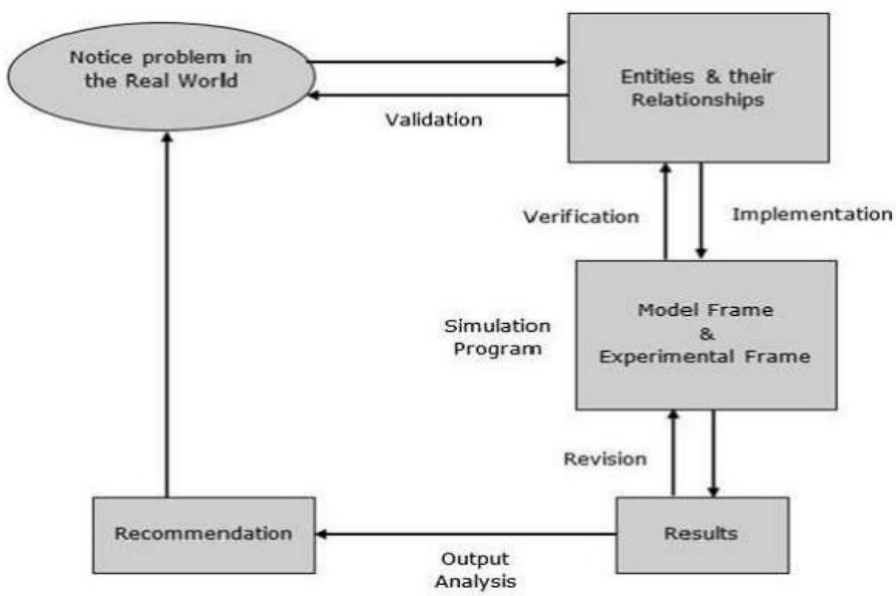
• Real-Time Interface: A plug-in card is used to replace part of the model with actual hardware by interfacing to it with actuators and sensors. This is called a hardware-in the-loop simulation or rapid prototyping and must be executed in real time.

• Code Generator: To produce efficient high-level source code from the block diagram or visual modeling interface. The control code will be compiled and used on the embedded processor. The language is usually C.

• Embedded Processor Interface: The embedded processor resides in the final products, and this feature provides communication between it and the computer-aided prototyping environment. This is called a full system prototype.

**9. Explain the role of modeling and simulation in the analysis of Mechatronics systems.**

**Modelling** is the process of representing a model which includes its construction and working. This model is similar to a real system, which helps the analyst predict the effect of changes to the system. In other words, modelling is creating a model which represents a system including their properties. It is an act of building a model.




**Step 1** − Examine the problem. In this stage, we must understand the problem and choose its classification accordingly, such as deterministic or stochastic.

**Step 2** − Design a model. In this stage, we have to perform the following simple tasks which help us design a model −

- Collect data as per the system behavior and future requirements.
- Analyze the system features, its assumptions and necessary actions to be taken to make the model successful.
- Determine the variable names, functions, its units, relationships, and their applications used in the model.
- Solve the model using a suitable technique and verify the result using verification methods. Next, validate the result.
- Prepare a report which includes results, interpretations, conclusion, and suggestions.

**Step 3** − Provide recommendations after completing the entire process related to the model. It includes investment, resources, algorithms, techniques, etc.

**Simulation** of a system is the operation of a model in terms of time or space, which helps analyze the performance of an existing or a proposed system. In other words, simulation is the process of using a model to study the performance of a system. It is an act of using a model for simulation.

Simulation models consist of the following components: system entities, input variables, performance measures, and functional relationships. Following are the steps to develop a simulation model.

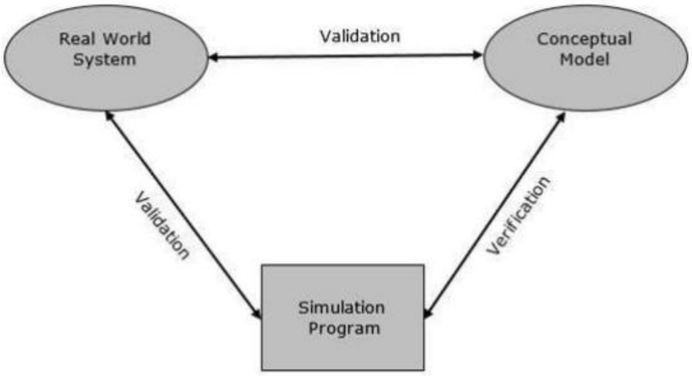
- **Step 1** − Identify the problem with an existing system or set requirements of a proposed system.
- **Step 2** − Design the problem while taking care of the existing system factors and limitations.
- **Step 3** − Collect and start processing the system data, observing its performance and result.
- **Step 4** − Develop the model using network diagrams and verify it using various verifications techniques.
- **Step 5** − Validate the model by comparing its performance under various conditions with the real system.
- **Step 6** − Create a document of the model for future use, which includes objectives, assumptions, input variables and performance in detail.
- **Step 7** − Select an appropriate experimental design as per requirement.
- **Step 8** − Induce experimental conditions on the model and observe the result.

**10. Discuss methods adopted to carry out the following process. i) Model validation. ii) Model verification.**

One of the real problems that the simulation analyst faces is to validate the model. The simulation model is valid only if the model is an accurate representation of the actual system, else it is invalid.

Validation and verification are the two steps in any simulation project to validate a model.

- **Validation** is the process of comparing two results. In this process, we need to compare the representation of a conceptual model to the real system. If the comparison is true, then it is valid, else invalid.
- **Verification** is the process of comparing two or more results to ensure its accuracy. In this process, we have to compare the model's implementation and its associated data with the developer's conceptual description and specifications.




Techniques to Perform Verification of Simulation Model

Following are the ways to perform verification of simulation model −

- By using programming skills to write and debug the program in sub-programs.
- By using "Structured Walk-through" policy in which more than one person is to read the program.
- By tracing the intermediate results and comparing them with observed outcomes.
- By checking the simulation model output using various input combinations.
- By comparing final simulation result with analytic results.

Techniques to Perform Validation of Simulation Model

**Step 1** − Design a model with high validity. This can be achieved using the following steps −

- The model must be discussed with the system experts while designing.
- The model must interact with the client throughout the process.
- The output must supervised by system experts.

**Step 2** − Test the model at assumptions data. This can be achieved by applying the assumption data into the model and testing it quantitatively. Sensitive analysis can also be performed to observe the effect of change in the result when significant changes are made in the input data.

**Step 3** − Determine the representative output of the Simulation model. This can be achieved using the following steps −

- Determine how close is the simulation output with the real system output.
- Comparison can be performed using the Turing Test. It presents the data in the system format, which can be explained by experts only.
- Statistical method can be used for compare the model output with the real system output.

**11. Why a system should be designed ergonomically? Give an example.**

The ergonomic design process is to create an item that gives the end user a comfortable, stress-free experience. This approach to design offers the following benefits:

- **Comfort –** Products that you use or touch should be comfortable. Would you want to sit on a chair that was hard and hurt your back? Would you enjoy using a keyboard that strains your wrists? Certainly not! Ergonomic product design helps improve comfort. It ensures that items can be used without placing unnecessary strain on the user.
- **Safety –** Safety has never been as crucial as in today's world. As consumers become more aware, they expect impeccable levels of safety. Would you want to use an electric device that had poor wiring? Or would you use a desk that had unsecured fittings? Ergonomic product design can vastly improve safety for both the manufacturer and the consumer.
- **Ease of use –** Products should be easy to use. Nothing is more frustrating for consumers than figuring out how to use a product. Ergonomic design can improve usability. It can help ensure a consumer has no stress or hassle.
- **Enjoyment –** Aside from ease of use, a product should also be enjoyable. If a product is enjoyable, consumers will be more likely to use it. Ergonomic design can help improve the consumer's enjoyment and give them a favorable experience when using the product.

As you can see, this design approach really can help create superb end products. The whole process revolves around the end user – it is also known as user-centric design. You look at what the consumer requires and figure out how to best meet their needs through your product design.

Real life example:
What is it? – Ergonomic desk
Why is it ergonomic? – Superb design with the comfort of the end user in mind
Notable feature – Crank handle to change desk height

Posturite is a company that produces a myriad of ergonomic product – we have featured several of their items in our list. Office desks are a fantastic example of this type of design process. We sit for prolonged periods of time at our desks.

The typical office working day is at least 7 hours – that's 7 hours you sat in the same position. To that end, your office desk must provide maximum comfort and usability. If you have a desk that is in the wrong position or makes you uncomfortable, your working days can be a nightmare.

The Desk Rite 200 Crank Sit-Stand desk addresses many common issues. Its main ergonomic feature is the crank handle – you can easily adjust the height of the desk to suit your own height and posture. Moreover, you can even make it a standing desk if you wish. This means that you can break up your day with periods of standing if you wish. Moreover, the desk area is spacious and made from sturdy but comfortable material – your wrists and arms will not suffer during the course of the day.

**12. Explain the process of building up of models for the following system with an example. i) Mechanical system. ii) Pneumatic system. iii) Hydraulic system**

**i) Mechanical System:**

1. **Structural Modeling:** Identify components such as gears, levers, and springs, and model their interactions and connections.
    - Example: Building a model of a simple lever system using SolidWorks to understand force distribution and mechanical advantage.
2. **Perspective of Modeling:** Focus on structural integrity, mechanical efficiency, and motion dynamics.
3. **Resulting Equations:** Develop equations describing forces, moments, and motion dynamics based on Newton's laws and mechanical principles.
4. **Physical Modeling:** Create physical prototypes or scaled models to validate theoretical predictions and understand real-world behavior.
    - Example: Constructing a scaled-down model of a suspension bridge to analyze load distribution and structural stability.
5. **Experimental Modeling:** Conduct experiments with the physical model to verify theoretical assumptions and refine the model.
    - Example: Testing different loads on the bridge model to observe stress distribution and deformation.

**ii) Pneumatic System:**

1. **Circuit Diagrams:** Develop circuit diagrams illustrating the connections between pneumatic components such as valves, cylinders, and compressors.
    - Example: Designing a circuit diagram for a pneumatic conveyor system to control airflow and actuator movements.
2. **State Graphs:** Create state graphs to visualize the system's operational states and transitions between them.
    - Example: Using state graphs to represent the states of a pneumatic valve (open, closed, partially open) and transitions between them.
3. **Perspective of Modeling:** Emphasize airflow dynamics, pressure regulation, and control logic.
4. **Resulting Equations:** Formulate equations describing airflow rates, pressure changes, and valve actuation based on fluid dynamics and control theory.
5. **Experimental Modeling:** Build physical prototypes to observe airflow patterns, pressure changes, and system response under different conditions.

- Example: Testing a pneumatic actuator prototype to measure response time and force output.

**iii) Hydraulic System:**

1. **Structural Modeling:** Model hydraulic components such as pumps, actuators, and valves, and analyze their interactions within the system.
    - Example: Using CAD software to create a 3D model of a hydraulic crane system to study load capacity and stability.
2. **Perspective of Modeling:** Focus on fluid dynamics, pressure regulation, and control strategies.
3. **Resulting Equations:** Develop equations describing fluid flow rates, pressure drops, and actuator forces using principles of fluid mechanics and control theory.
4. **Physical Modeling:** Construct physical models of hydraulic circuits to observe fluid flow, pressure changes, and actuator movements.
    - Example: Building a small-scale hydraulic press model to demonstrate pressure transmission and force amplification.
5. **Experimental Modeling:** Conduct experiments with the physical model to validate theoretical predictions and optimize system performance.
    - Example: Testing different hydraulic valve configurations to minimize pressure losses and improve system efficiency.

In summary, building models for mechanical, pneumatic, and hydraulic systems involves a multidisciplinary approach that integrates various modeling techniques, perspectives, and experimental validation to gain insights into system behavior and optimize design parameters.