AE 230 - **Modeling and Simulation Laboratory**

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Credit Structure:1.5-0-2-5 (L-T-P-C)

Introduction: Objectives, concepts and types of models.

Modeling: Analytical and experimental modeling of simple mechanical, hydraulic, thermal and structural systems. Transfer function and block diagram representation.

Time response: First and second order systems. System representation and simulation using MATLAB, SIMULINK and AMESim tools.

Quantifying Uncertainty: Use of simulation to quantify the uncertainty in system response and performance caused by uncertainty in model parameters and inputs.

Special topic: Software simulation of stiff systems and impact of integration time step on methodology and response.

Lab project: Application of modelling and simulation methodologies to a complex engineering system.

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References:

1. Ogata, K., System Dynamics, 4th Ed. Pearson Education LPE, 2004.
2. Doebelin, E. O., System Dynamics: modeling, analysis, simulation, designs New York: Marcel Dekker, 1998.
3. User Manuals for the Setups ~~**and AMESim Engg. System Modelling & Simulation Software Tool**~~
4. IJ Nagrath and M Gopal, Systems Modelling and Analysis, Tata McGraw Hill, fourteenth reprint, 2000.

What is Modelling?

<u>Modelling</u> is the determination of those quantitative features which describe the operation of the *system*

Quantitative does not always imply mathematical

System : is a collection of components wherein individual components are constrained by connecting interrelationships such that the system as a whole fulfils some specific functions in response to varying demands

Some examples of the system:
1) Public mass transportation system
2) Distillation system
3) autopilot system
4) Judicial system

Why Modelling?

1) Modelling helps in creating virtual systems

2) Modelling helps in creating equivalent systems

3) Modelling helps in problem decomposition

4) Modelling helps in identifying interrelationships

5) Modelling helps in understanding the system

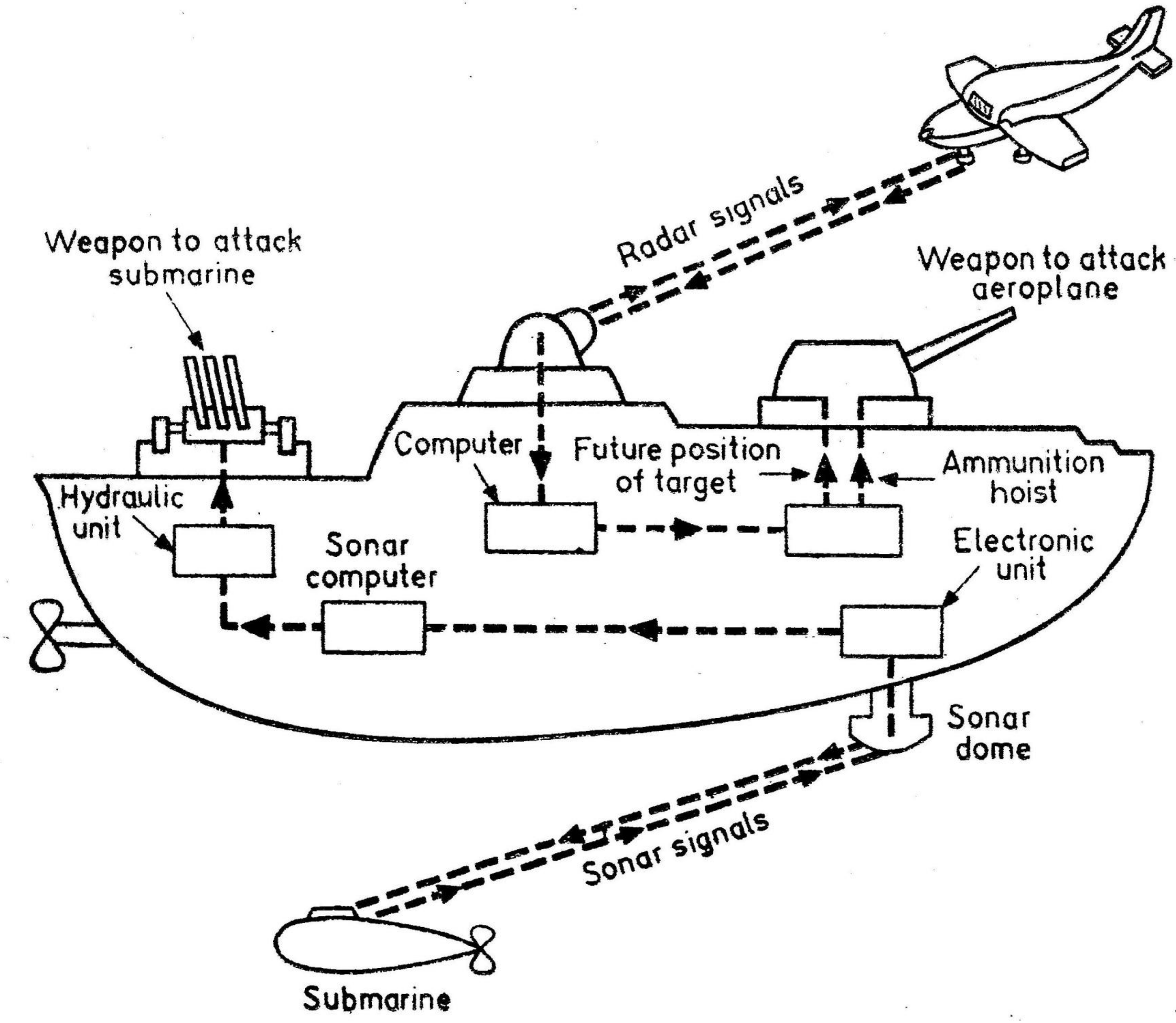


Fig. 1.8 A modern warship.

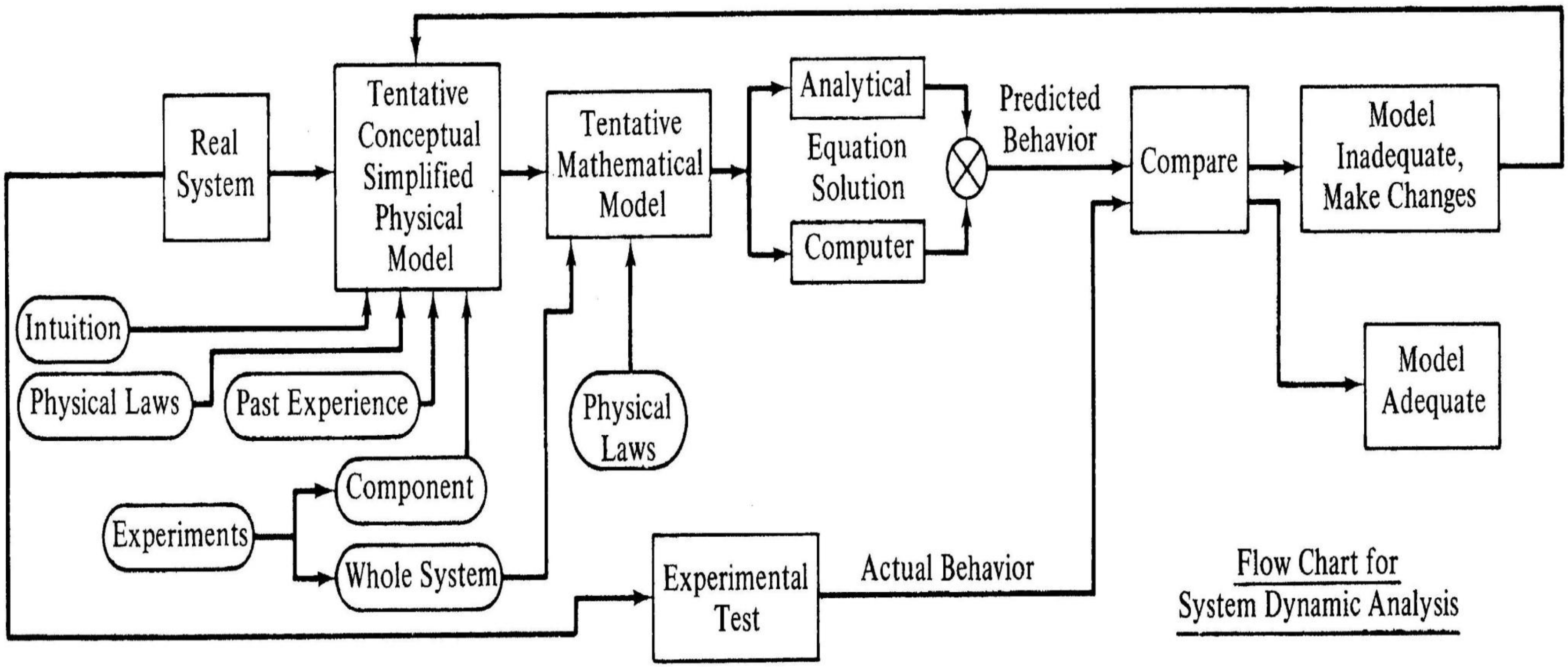


Figure 1-12 The system modeling process.

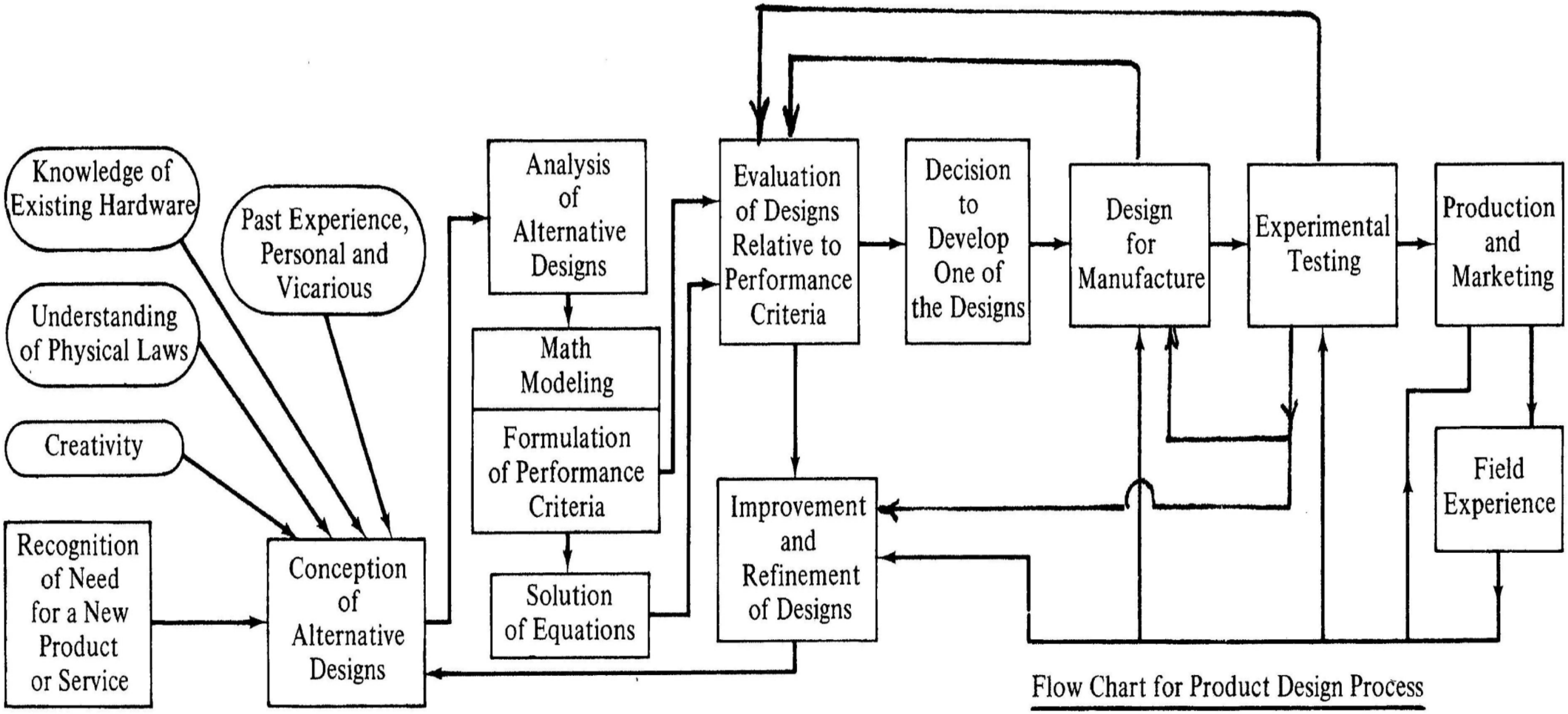
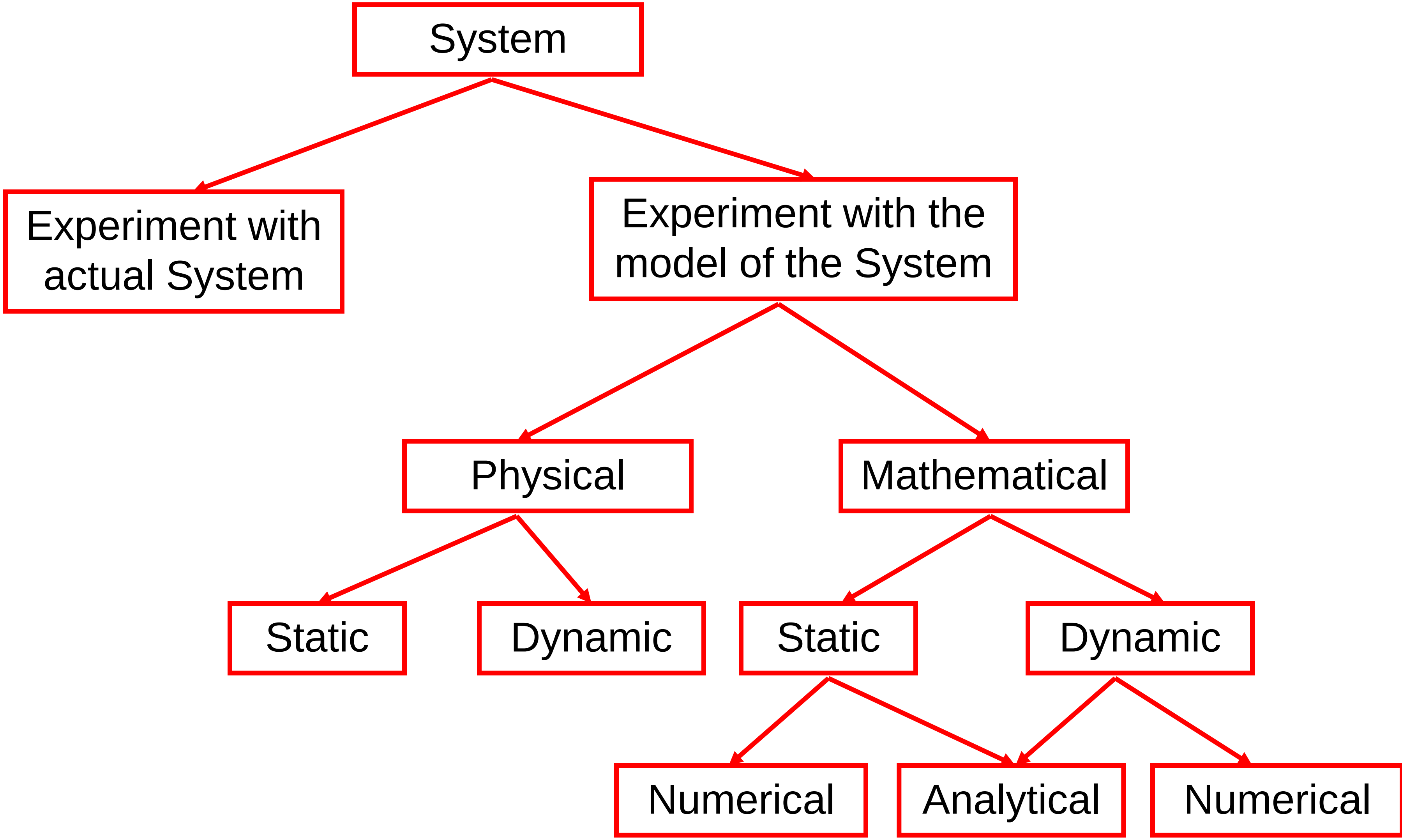


Figure 1-13 The product design process.

Types of Models



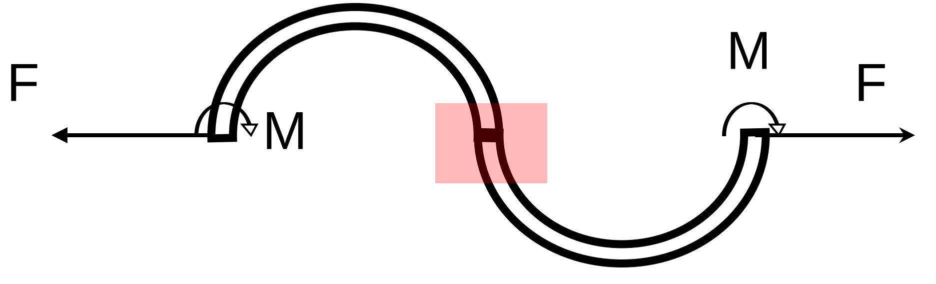
Types of model?

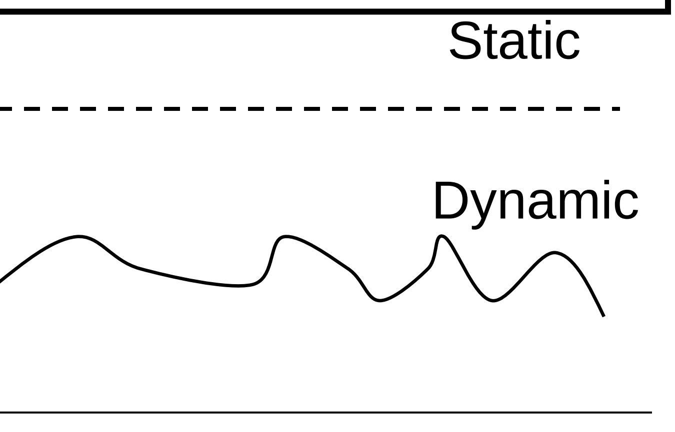
1) Physical Model, 2) Analog model, 3) Scaled model, 4) digital model

1)Physical Model : Imaginary physical system resembling the actual system in certain features but which is simpler and therefore more amenable to studies.:- Static & Dynamic

Static: - Joint which is part of a super structure is tested in isolation under similar loading conditions. Load is constant.

Dynamic: - Joint which is part of a super structure is tested in isolation under similar dynamic loading conditions. Load is time varying.





Types of model?

2) Analog model: Models having same differential equations are called analog models. First order system can be a RC circuit. All knowledge of RC can be used for a model represented as first order system.

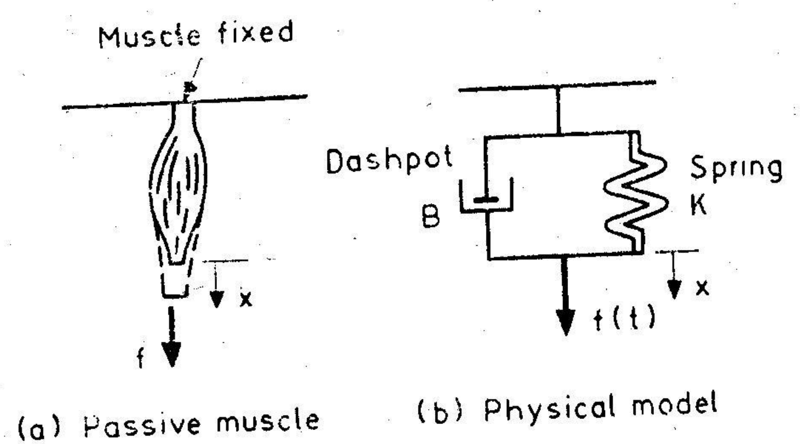


Fig. Physical model of a passive muscle.

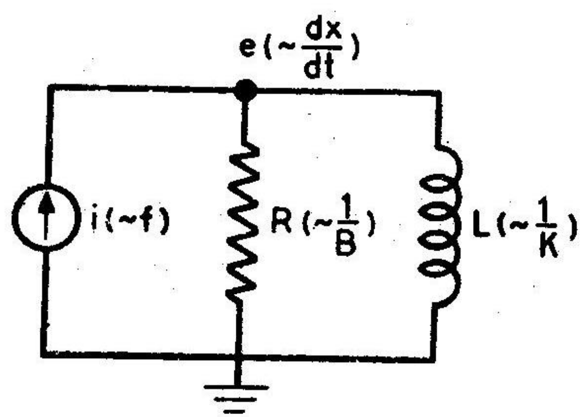


Fig. Electrical analog of the system of Fig. 1,10(b).

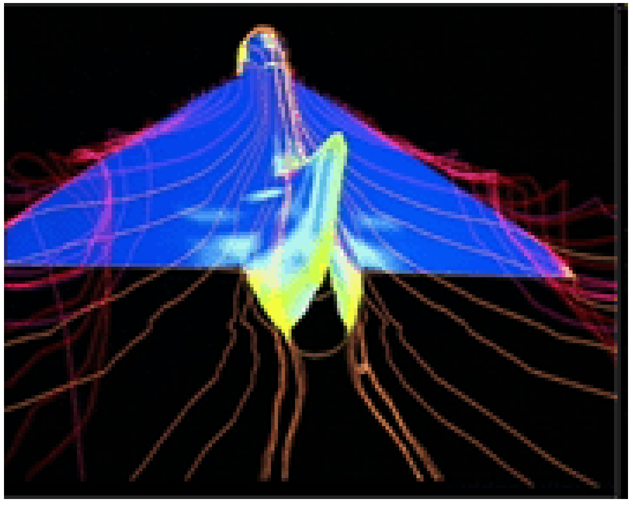
Types of model?

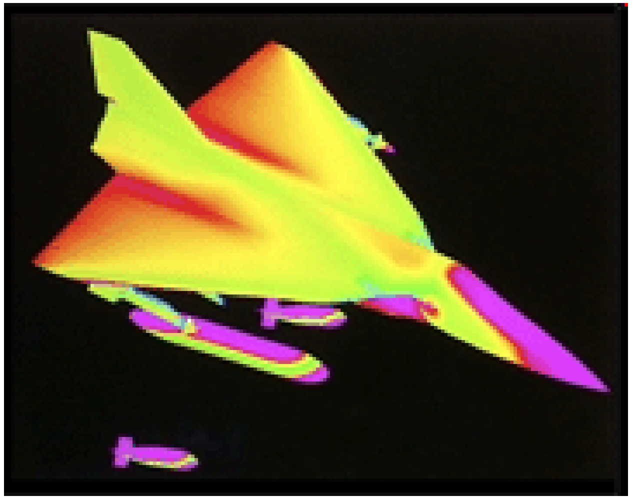
3) Scaled model: Model is scaled down/up of the physical system. Scaling effects are important.
Testing of aircraft model for static and dynamic aerodynamics coefficients. Reynolds number effects become important.

http://www.ada.gov.in/Activities/Designanalysis/AeroDynamics/Wind_Tunnel_Testing/wind_tunnel_testing.html

Types of model?

4) Digital model: Model is expressed in the form of mathematical equations: Continuous, discontinuous, discreet These are most flexible in terms of modification and can tackle complex equations very easily. Most commonly used technique for simulation. Numbers generated can be easily converted into convenient units or forms.



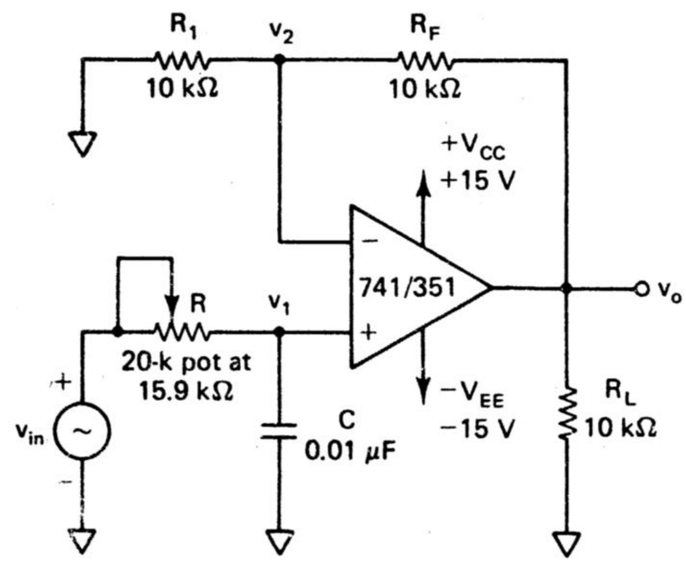


http://www.ada.gov.in/Activities/Designanalysis/AeroDynamics/Computational_Fluid_Dynamics/computational_fluid_dynamics.html

Example : Electronic Filter Design

First order filter. Opamp, resistors, capacitors

$$\frac{v_o}{v_{in}} = \frac{A_F}{1 + j(f / f_H)} \qquad A_F = 1 + \frac{R_F}{R_1}$$



f is input frequency

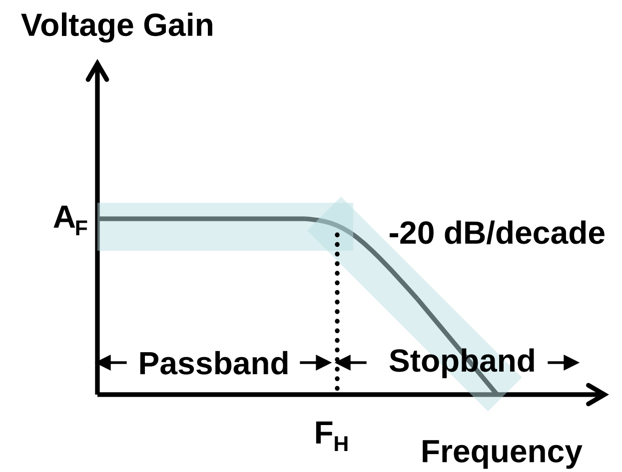
f_H is higher cutoff frequency

$$f_H = \frac{1}{2\pi RC}$$

Selection of resistor, capacitors, opamp

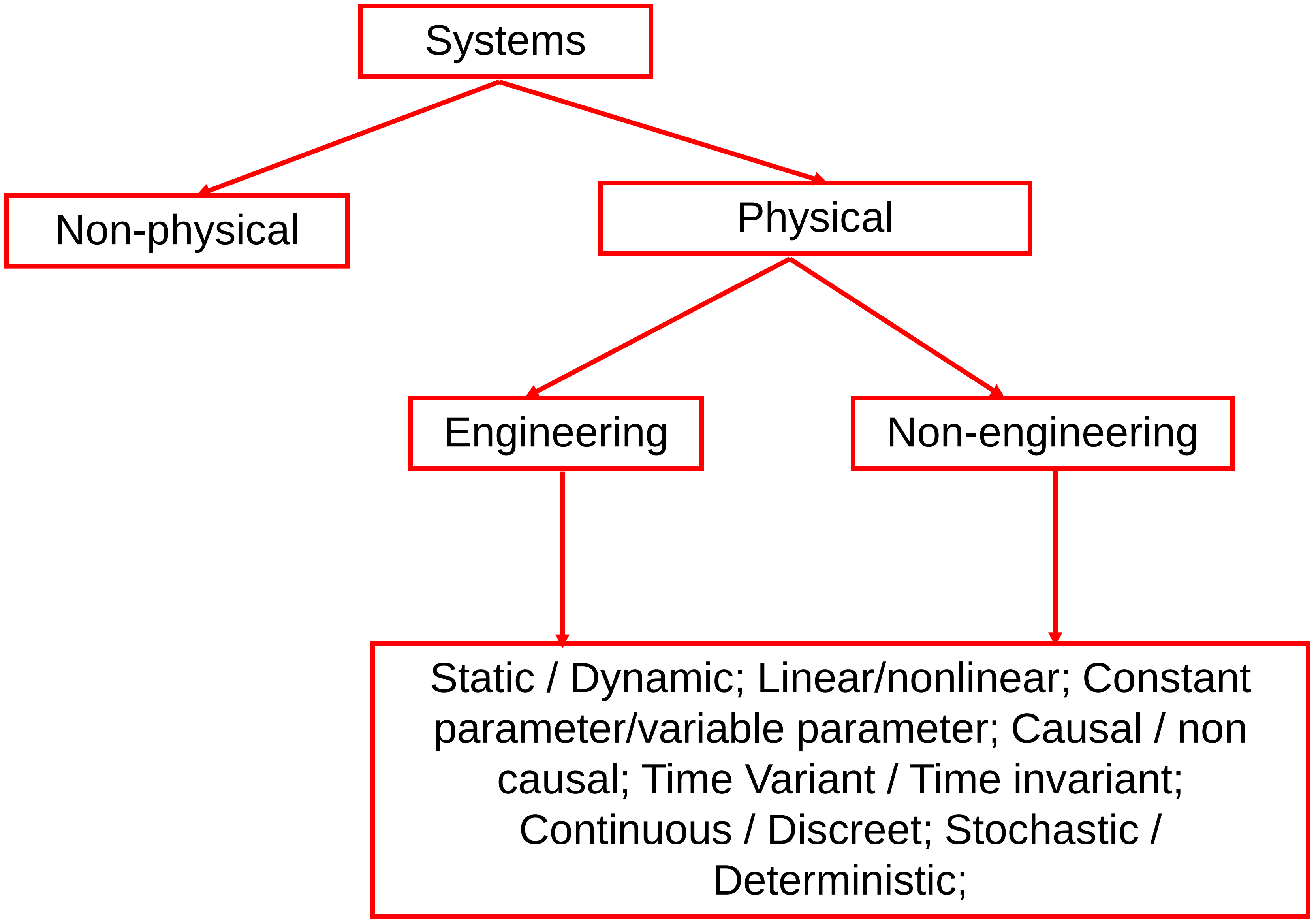
Sensitivity Analysis to understand the component tolerance

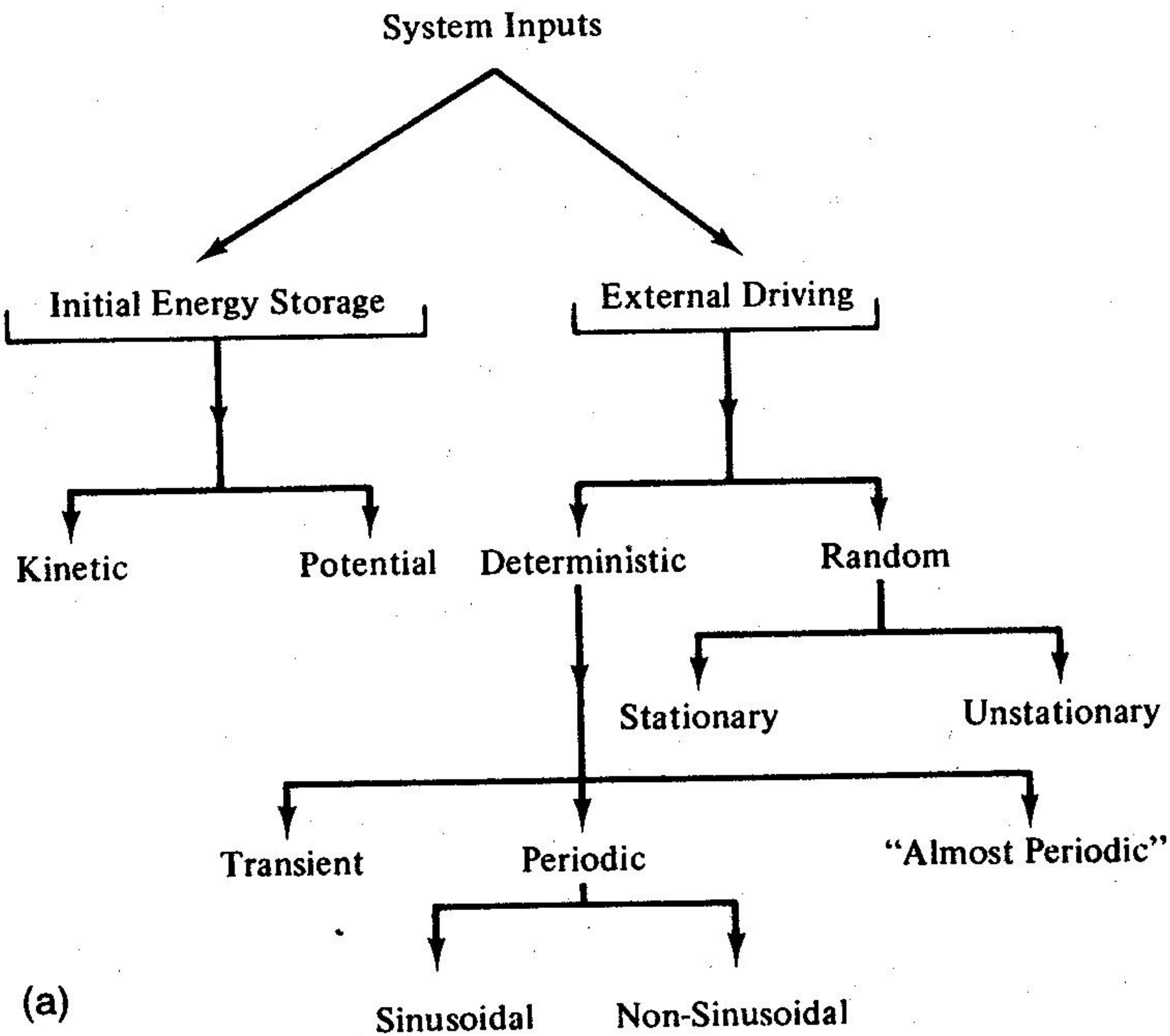
System Designer



Frequency vs Amplitude

Types of Systems




System Inputs
Initial Energy Storage
External Driving
Kinetic
Potential
Deterministic
Random
Stationary
Unstationary
Transient
Periodic
"Almost Periodic"
Sinusoidal
Non-Sinusoidal

(a)

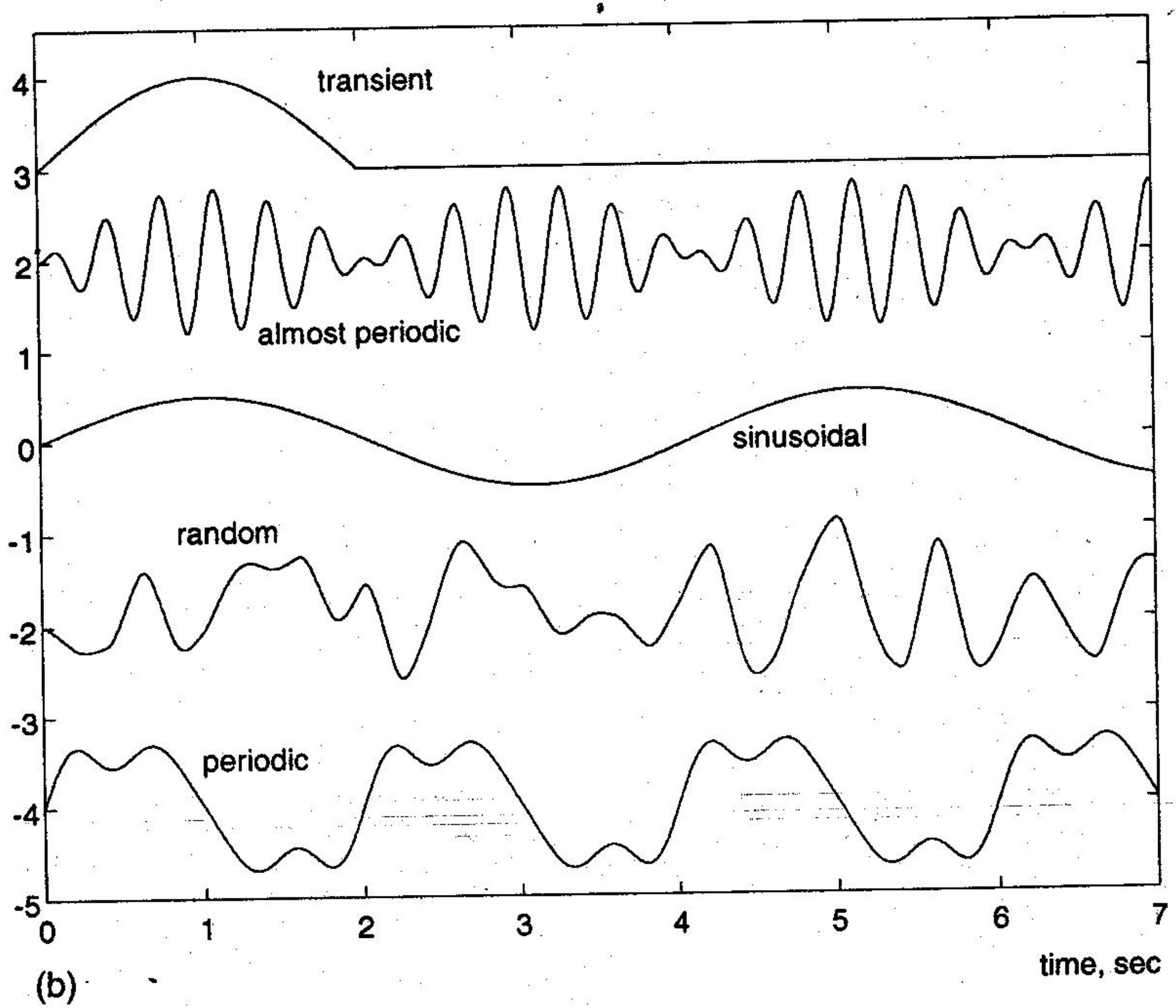


Figure 1-5 Classification of inputs.

Model Type Number	Nature of the Medium						Time-Variation of System Parameters			
	Continuous (Field Problems)	Discrete (Network Problems)	Space-Variation of Parameters		Nonlinear	Linear	Random	Deterministic, Variable	Deterministic, Constant	
			Variable	Constant						
1	X		X		X		X			
2	X		X		X			X		
3	X		X		X				X	
4	X			X	X		X			
5	X			X	X			X		Most realistic, most difficult to solve ↑
6	X			X	X				X	
7	X		X			X	X			
8	X		X			X		X		
9	X		X			X			X	
10	X			X		X	X			
11	X			X		X		X		
12	X			X		X			X	
13		X			X		X			
14		X			X			X		Least realistic, easiest to solve ↓
15		X			X				X	
16		X				X	X			
17		X				X		X		
18		X				X			X	

Figure 1-9 Classification of system models.