Lecture 3.0

Forces in Structures & Machines

3.0 Forces in Structures & Machines

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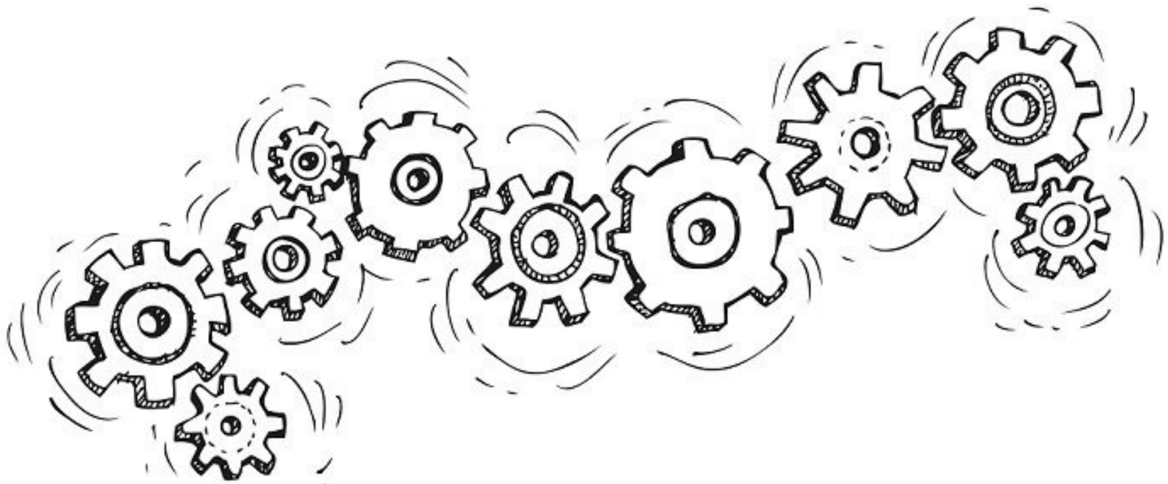


3.1 Overview

- Mechanical Engineers design Products, Physical Systems, and Software & Hardware.
- They must apply mathematics and physical principles to model, analyze, and predict system behavior.

3.1 Overview

- Successful design is dependent on effective engineering analysis.
- Effective engineering analysis also require an understanding of ***forces in structures and machines*** and their tendency either to remain stationary or move.
- Mechanical engineers also evaluate position, velocity, and acceleration of machines, as well as the forces and torques that make them move.

3.1 Overview

The fundamental principles that form the basis of mechanics are Newton's three laws of motion:

- Every object remains in a state of rest or uniform motion of constant velocity unless an external unbalanced force acts upon it.
- An object of mass m, subject to a net force F, experiences an acceleration in the same direction as the force with a magnitude directly proportional to the magnitude of the force and inversely proportional to the mass of the object. This relationship can be expressed as $\boldsymbol{F} = m\boldsymbol{a}$.
- The forces of action and reaction between two objects are equal, opposite, and collinear.

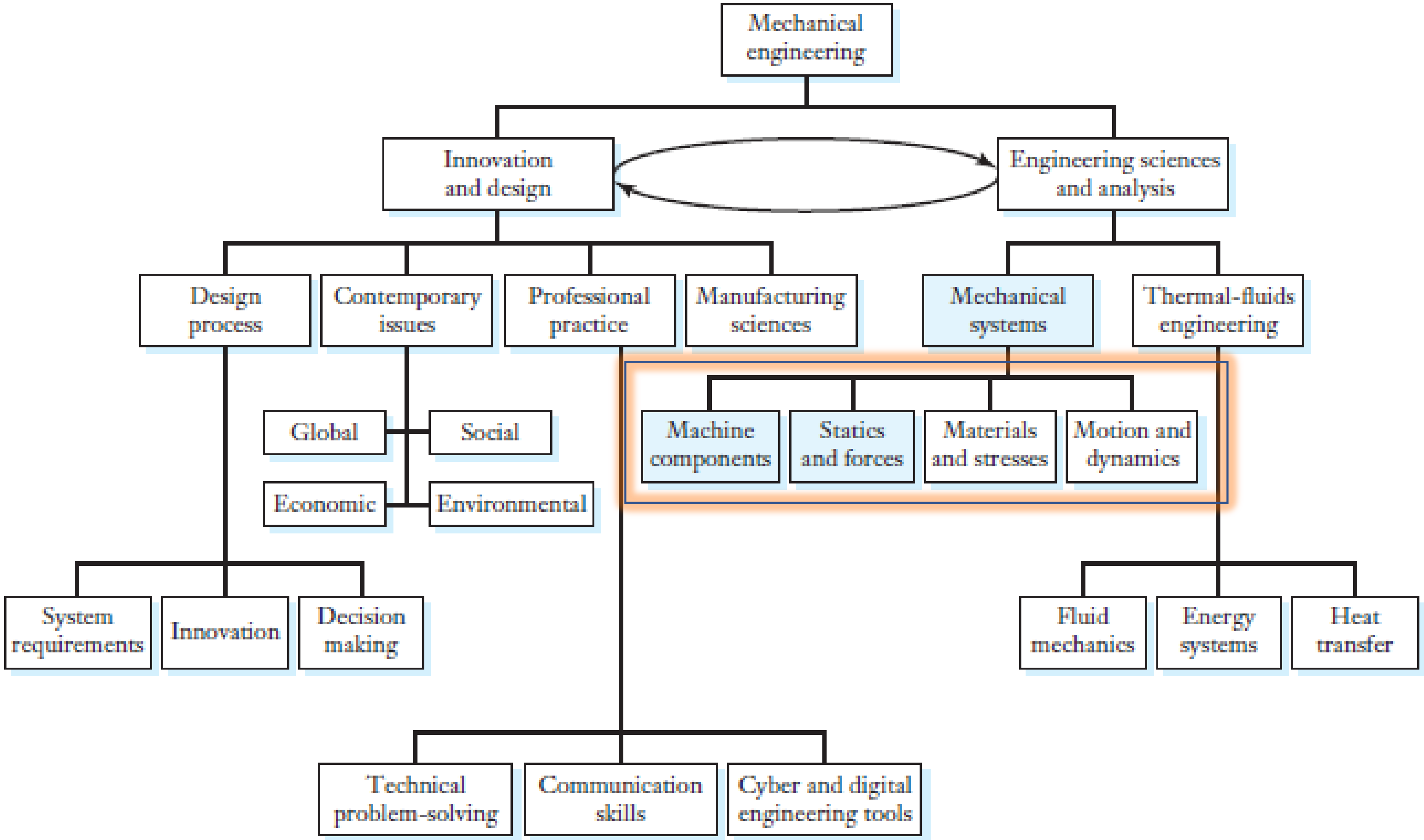


Figure 4.2 Relationship of the topics emphasized in this chapter (shaded boxes) relative to an overall program of study in mechanical engineering

3.1 Overview

- Force systems and machine components fall under the Engineering sciences and analysis branch but provide support for key decisions in the design of innovative systems.

3.2 Forces in Rectangular & Polar Forms

- We first need to describe a force’s magnitude and direction to determine the influence of forces on a structure or machine.
- The properties of forces, equilibrium, and motion in two and three dimensions are also subjects that you will encounter later in the mechanical engineering curriculum.
- These are extensions to what you have learned in Physics and Mathematics.

3.2 Forces in Rectangular & Polar Forms

- Forces are vector quantities since their physical action involves both direction and magnitude.
- The magnitude of a force is measured by using the dimensions of **Pounds (lb) or Ounces (oz)** in the USCS and **Newtons (N)** in the SI.

Table 4.1

Conversion Factors Between USCS and SI Units for Force

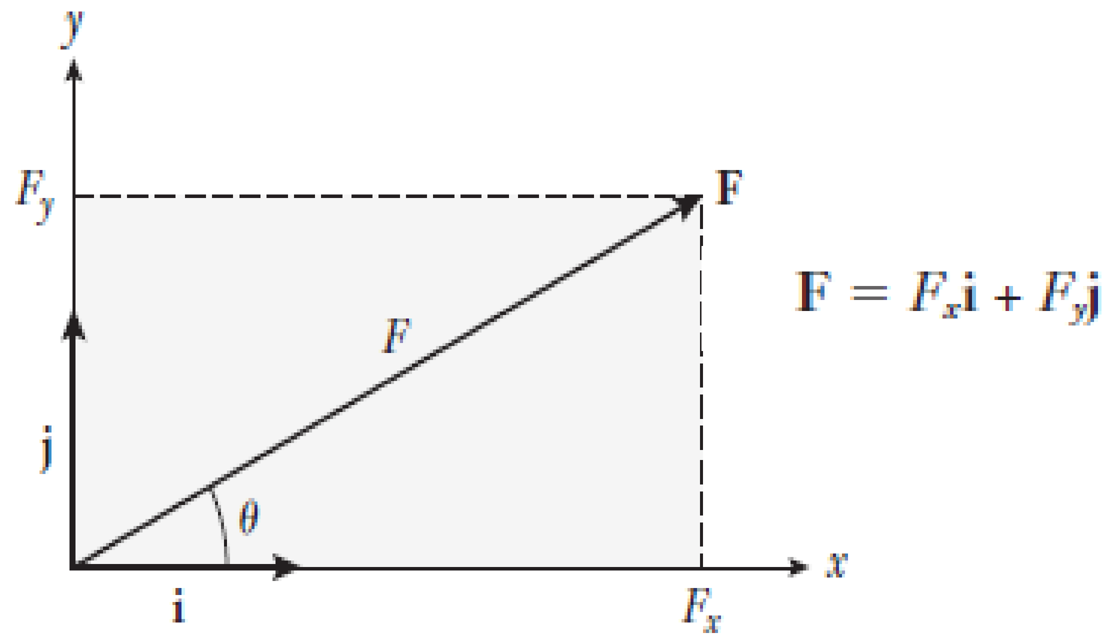
lb	oz	N
1	16	4.448
0.0625	1	0.2780
0.2248	3.597	1

3.2.1 Rectangular Components

- Force *vectors* are denoted by using boldface notation, as in **F.**
- One of the common methods used to represent the influence of a force is in terms of its horizontal and vertical components.
- The force **F** can be broken down into its *rectangular components* along directions for the *x*- and *y*-axes.

Figure 4.3

Representing a force vector in terms of its rectangular components (F_x, F_y), and its polar components (F, θ).



- The *unit vectors* **i** and **j** are used to indicate the directions in which *Fx* and *Fy* act.
- Vector **i** points along the positive *x*-direction, and **j** is a vector oriented in the positive *y*-direction

3.2.2 Polar Components

- Rather than thinking about a force in terms of how hard it pulls rightward and upward, you could tell someone **how hard** the force pulls, and in which **direction** it does so.
- Instead of specifying *Fx* and *Fy*, we can now view the force vector **F** in terms of the two numbers ***F*** and $\boldsymbol{\theta}$.

3.2.2 Polar Components

$$F_x = F\cos\theta \qquad \text{(polar to rectangular)}$$
$$F_y = F\sin\theta \tag{4.2}$$

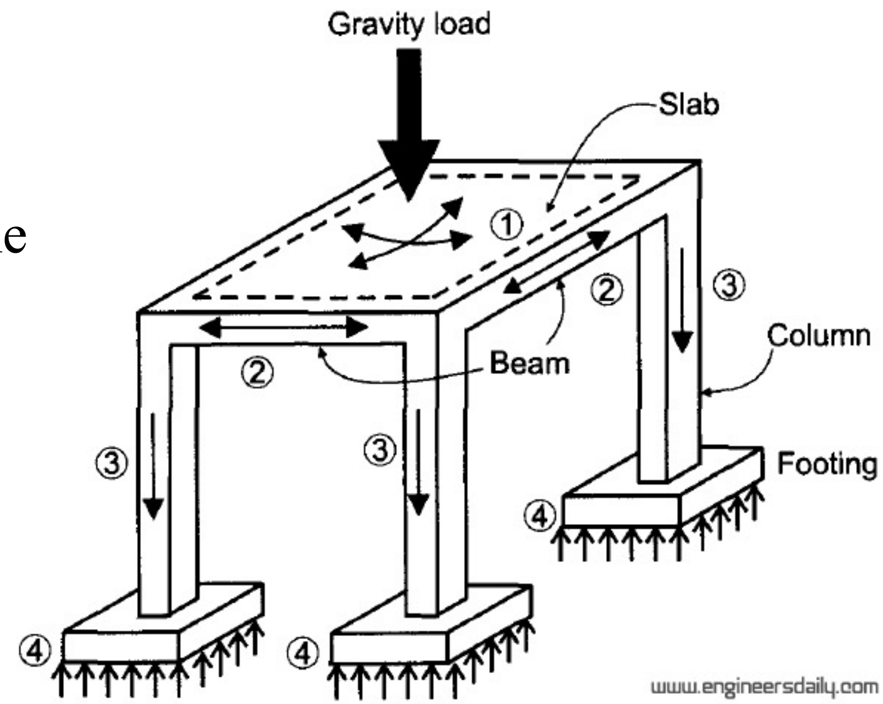
$$F = \sqrt{F_x^2 + F_y^2} \qquad \text{(rectangular to polar)}$$
$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) \tag{4.3}$$

3.2.3 Force Analysis

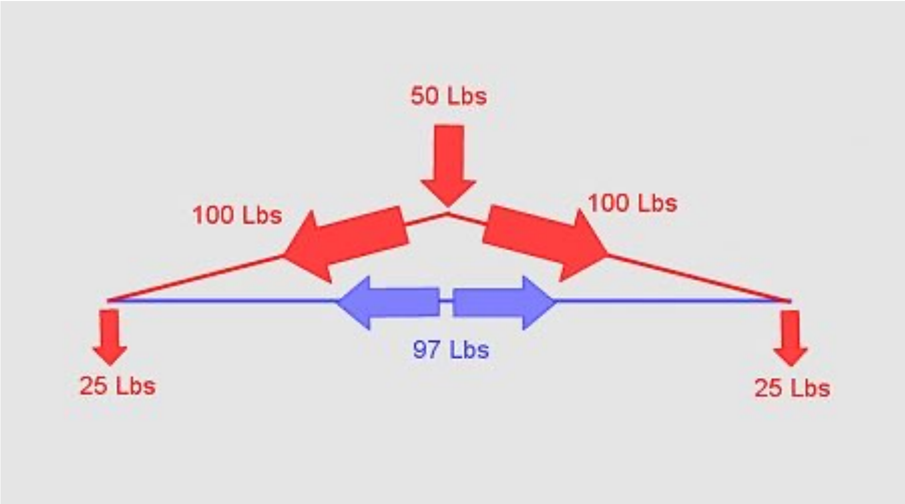
- Resultant of several forces
- Moment of a force
- Equilibrium of forces and moments
- Particles and rigid bodies
- Free body diagrams

3.3 Force Flow & Load Path

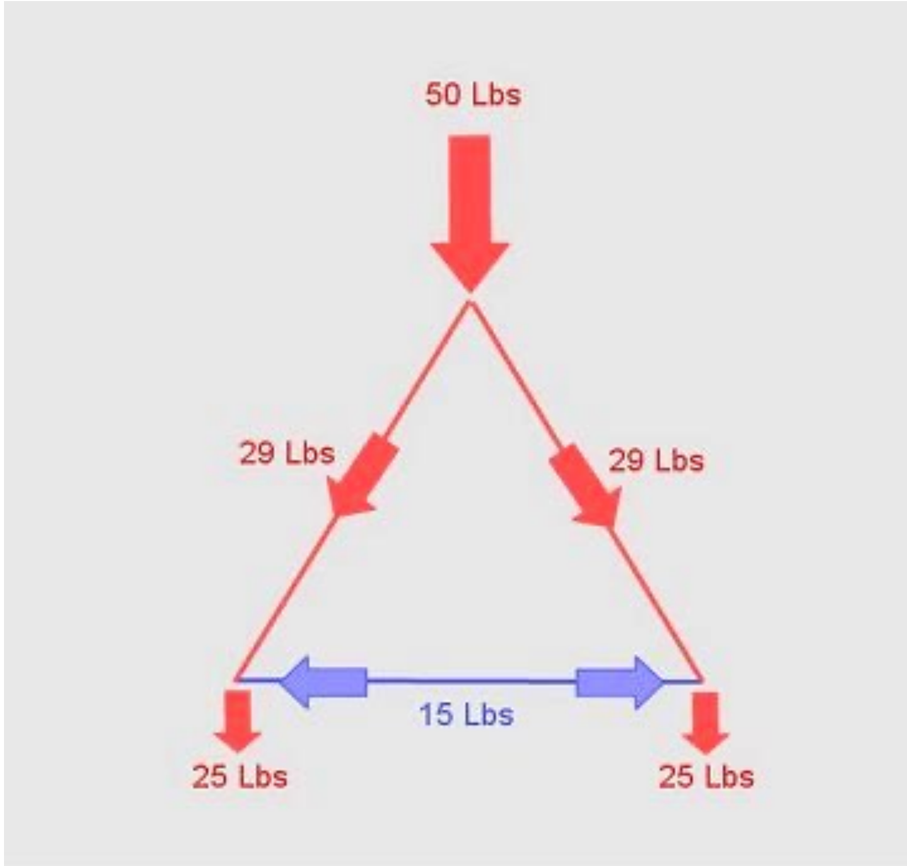
Understanding How a Force or Load travels through a physical system will help an engineer to quickly evaluate the system's ability to carry the external loads and effectively devise ways to optimize its design.



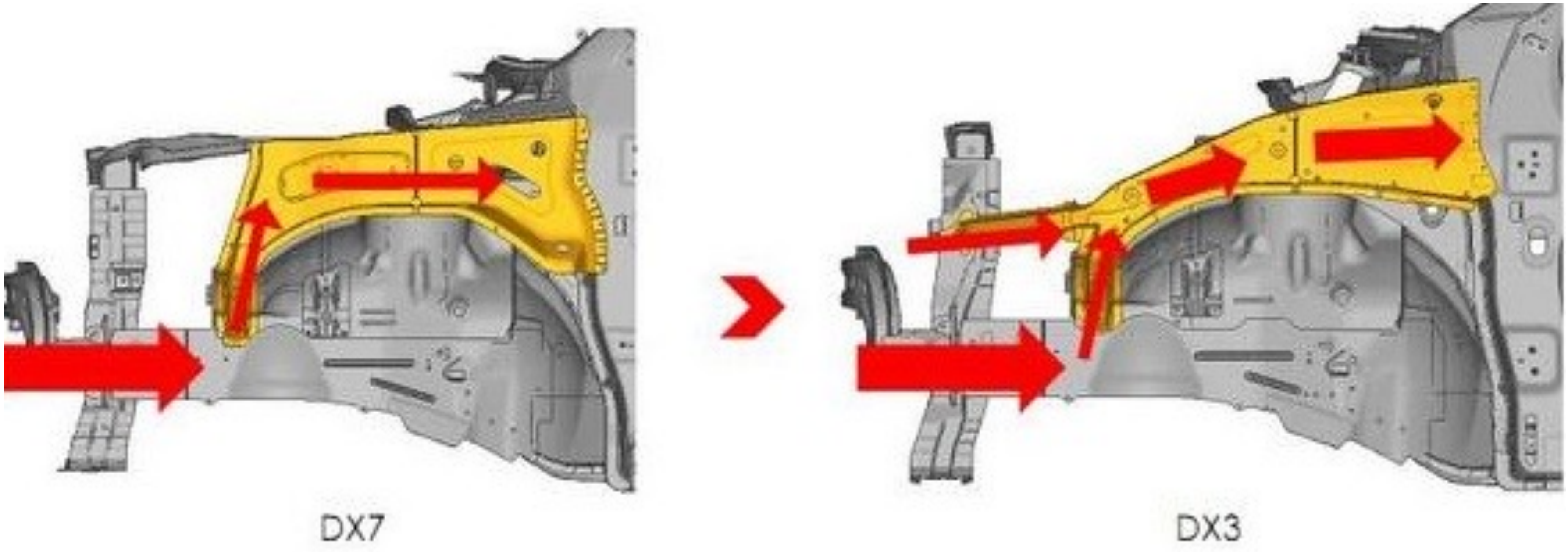
3.3 Force Flow & Load Path



The diagrams shows how the load values differ with changing orientation of the load bearing components.



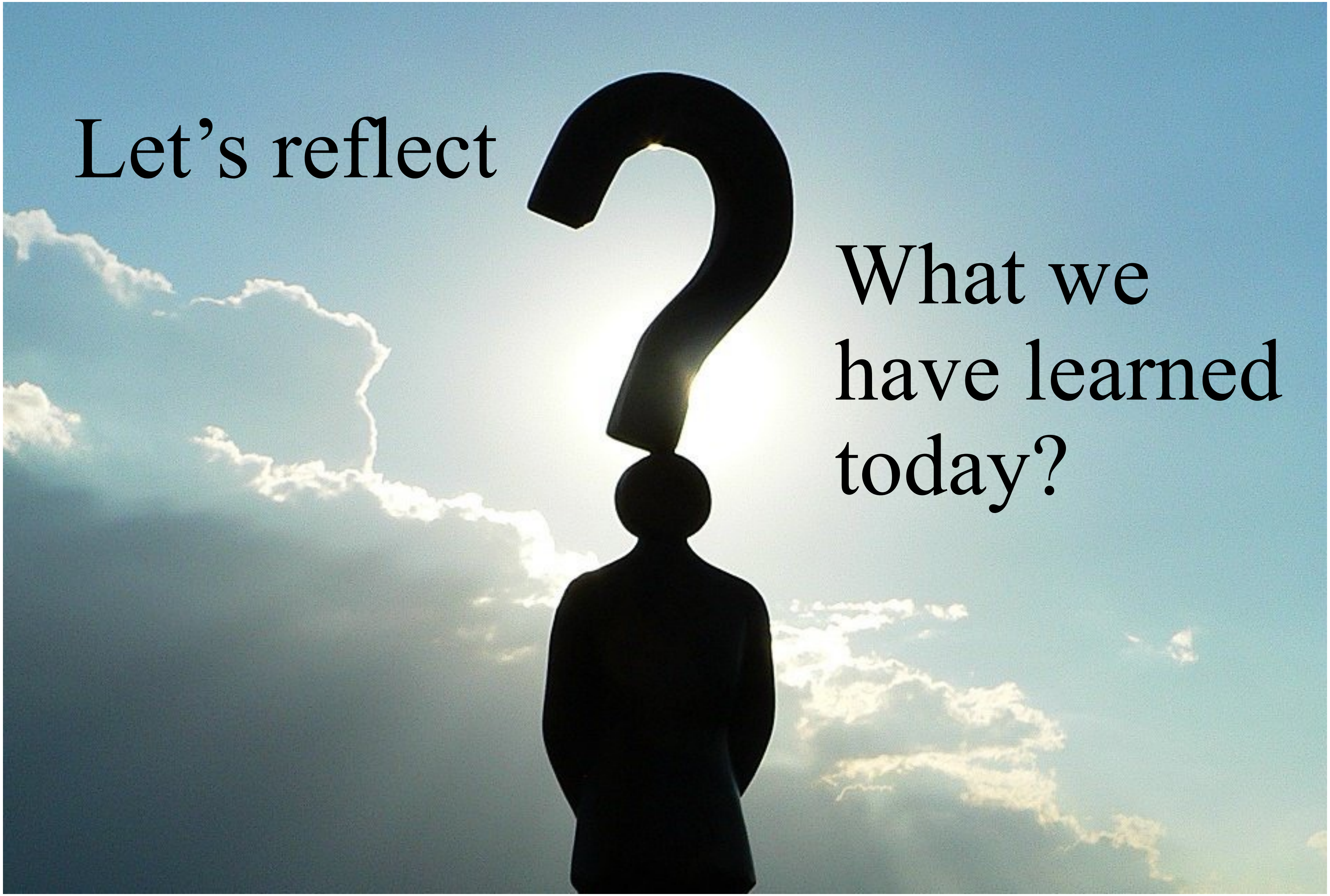
3.3 Force Flow & Load Path

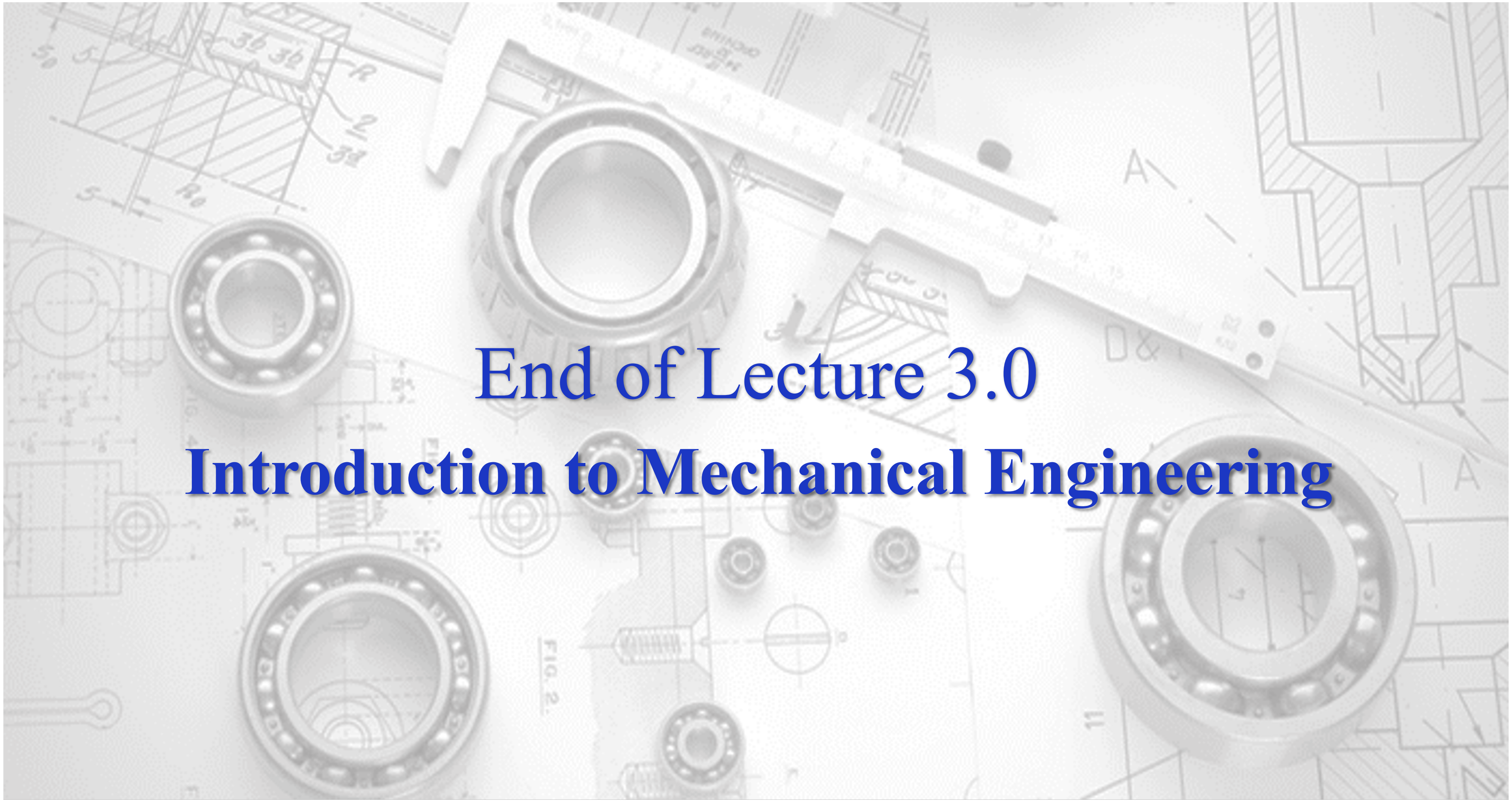


The diagram shows how understanding Load Path in the major components of the front end of a car can help improve design of components of the main structure.

Summary

- Engineers often perform a force analysis to see whether a design will be feasible and safe.
- One of the skills that mechanical engineers develop is the ability to apply equations to physical problems clearly and consistently.
- Selecting the object to be included in a free body diagram, choosing the directions for coordinate axes, and picking the best point for balancing moments are some of the choices that you need to make in solving problems of this nature.


Let’s reflect
What we
have learned
today?



End of Lecture 3.0

Introduction to Mechanical Engineering