LECTURE 2

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**References**: Chapter 1 of Juvinall
Chapters 2 and 3 of Bisplinghoff et al.

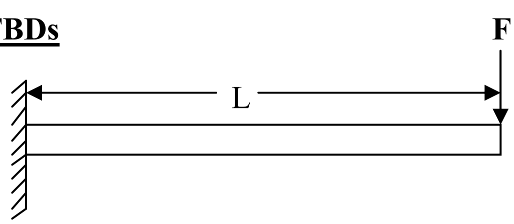
**Solving a Design Problem**

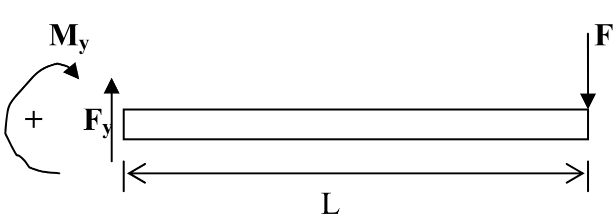
1) Determine the applied loading
   Service/operating loads from full scale experiments, service failure loads
2) Load Analysis using FBD+Laws; determine+reactions+internal forces → critical sections
3) Stress analysis → critical points
4) Find the critical locations
5) Apply failure criterion

Juvinall recommends that problem solutions be organized using the following seven steps (and that we will follow in the class):

1) State briefly what is known; **Known** or Given
2) State concisely what is to be determined; **Find**
3) **Schematic** and the given data;
   - Sketch the system + free body diagram
   - Critical points and dimensions on the figure
   - Record all material data and other parameters
4) **Decisions** – record your choices/selections (used in design problems mostly)
5) **ASSUMPTIONS**; how you model the problem, list all idealizations to reduce the problem to a manageable problem
6) **Analysis**
   - Work with the equations as long as possible before substituting numbers
   - Do additional FBD's
   - Check units
   - Consider magnitudes and numerical values and signs if they seem reasonable
7) **Comments**: Discuss your results. Go back to assumptions, how better results might be ontained.

**FBDs**



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**Forces:**

Contact Forces
- Frictional force
- Tension
- Normal
- Air resistance

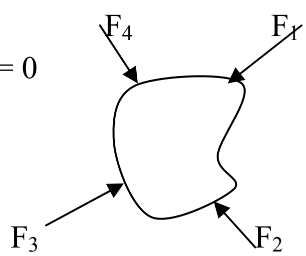
Action at a distance
- Electrical
- Magnetic
- Gravity

## Newton's Laws for a Body

**Newton's 1st law:** If the forces acting upon on object are balanced, then the acceleration of that object will be zero. (constant speed)

$F_{net} = 0$

$M_{net} = 0$

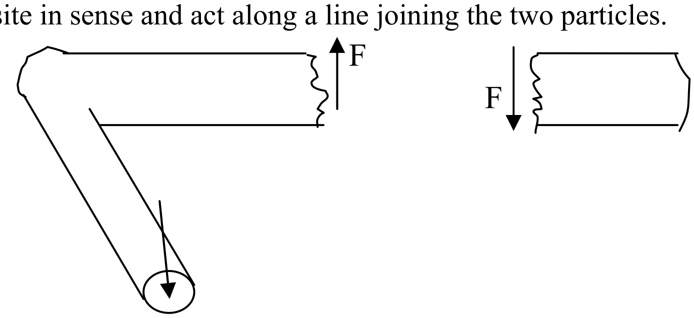



**Newton's 2nd law (Law of motion):** A particle which is unrestrained and acted upon by a force vector **F** acquires an acceleration **a** which is proportional in magnitude to the magnitude of F and along a line of action and in the sense of direction of **F**.

$\mathbf{F}_{net} = m.\mathbf{a}$

$\mathbf{M}_{net} = I.\boldsymbol{\alpha}$

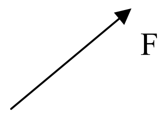
**Newton's 3rd law (Law of action and reaction):** When two particles exert forces one upon the other whether in direct contact or at a distance from eachother these forces are equal in magnitude and opposite in sense and act along a line joining the two particles.



F

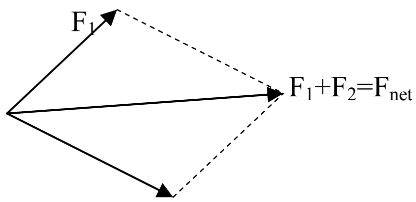
**Properties of Forces**

1. Forces are vectors.

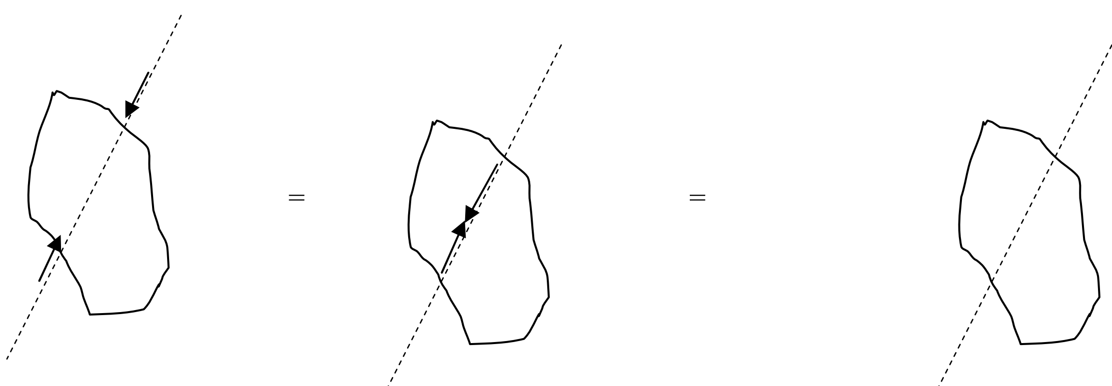



2. Parallelogram Law

Resultant of forces at a point is sum of the forces added vectorially;

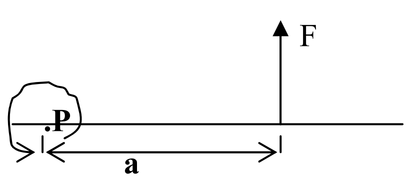



3. Forces are transmissible.




When a force is acting upon a rigid body it may be translated along its line of action, so that it acts on any points of rigid body when coincide with line of action.

**Moments About a Point**




$M_p = F.a$

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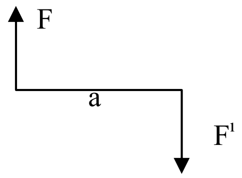
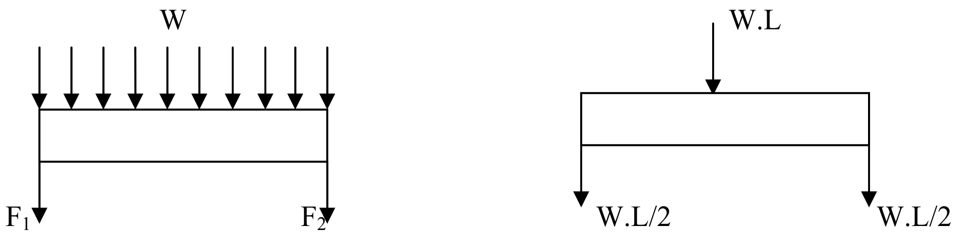
couples

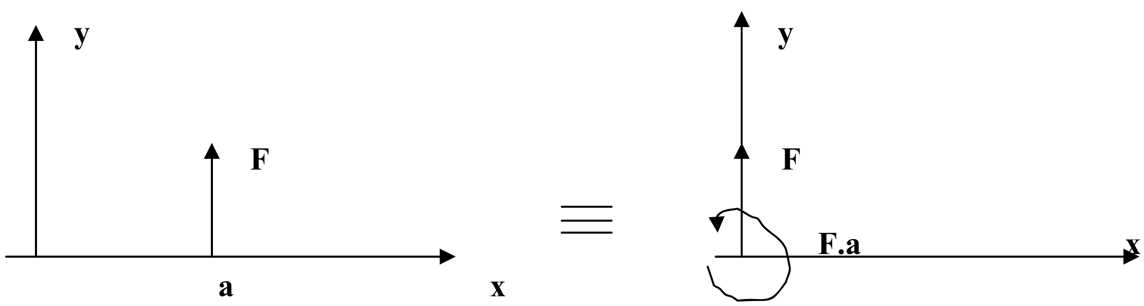


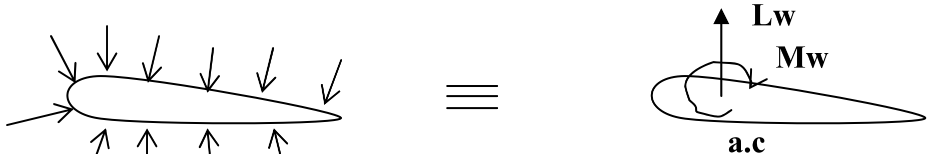

$\mathbf{M} = \mathbf{F}.a$

**Equipollent forces (equally powerful forces);** when either the system of forces may be replaced by others

1) The resultant of the force system is equal to the resultant of the forces of the other system.
2) The sum of the moments of the forces of one system about any arbitrary points in equal to the sum of the moment of the forces of the other system about the same axis.



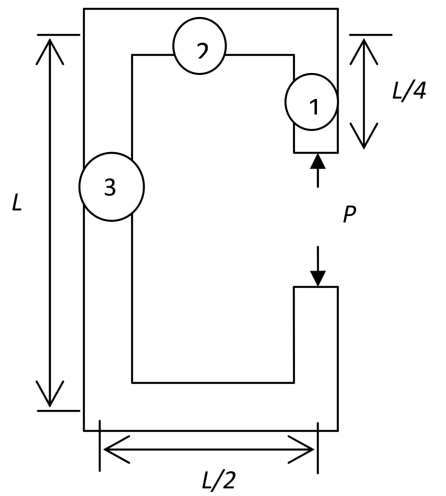

Equipollent but not equivalent

**Problem**

Step 1) **<u>Known</u>**: geometry, load P

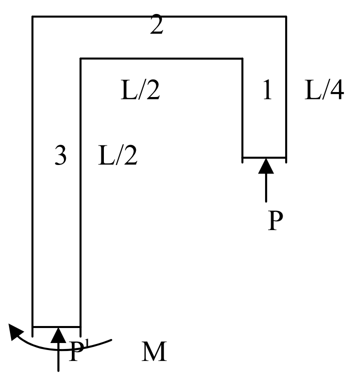
Step 2) **<u>Find</u>**: free body diagrams for parts 1, 2 and 3 and the internal forces and the moments in each section.

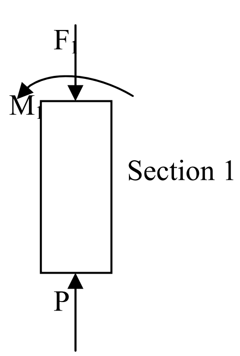
Step 3) **Schematics**:




Step 4) **<u>Assumptions</u>**: neglect weight

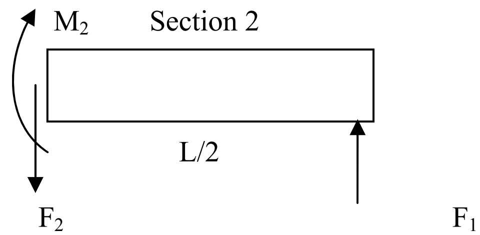
Step 5) **<u>Analysis</u>**: using partial free body diagrams



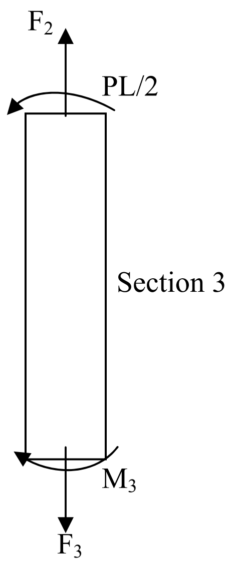

$\sum F=0$, $P-F_1=0$, $P=F_1$

$\sum M=0$ $M_1=0$




$\sum F=0$, $F_1-F_2=0$, $F_1=F_2$

$\sum M=0$, $F_1.(L/2)-M_2=0$, $M_2=PL/2$




$\sum F=0$, $F_2-F_3=0$, $F_2=F_3$

$\sum M=0$, $M_3-PL/2=0$, $M_3=PL/2$

**<u>Glossary</u>:**

**Equipollent:** having equal force or power

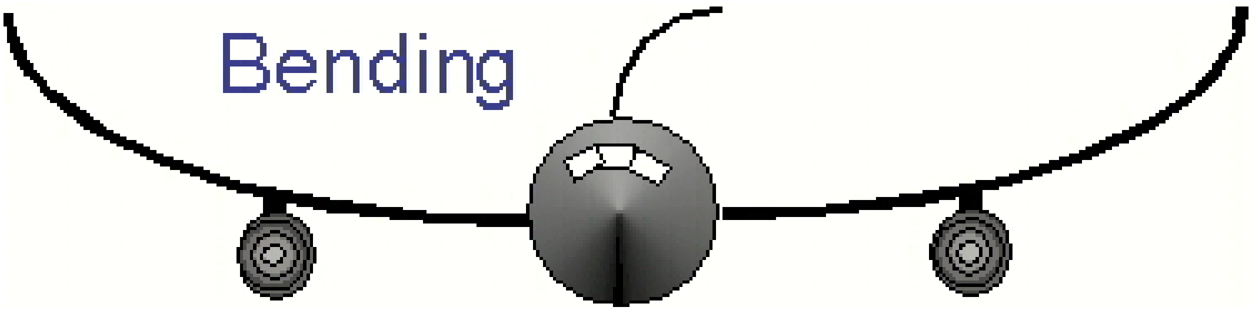



**Figure 1**:**Wing deflection of the wings and tail of an aircraft.**

The force distribution due to wind loading, causes bending on the wings of the aircraft. A strictly rigid material should not be chosen because this will cause failure easily. They should be flexible enough to stay as a complete wing during the flight at high or low altitudes! Although, the real deflections in the wings and tail are not as much as shown in the figure, it is drawn in an exagerated manner to increase the visibility of deflections.

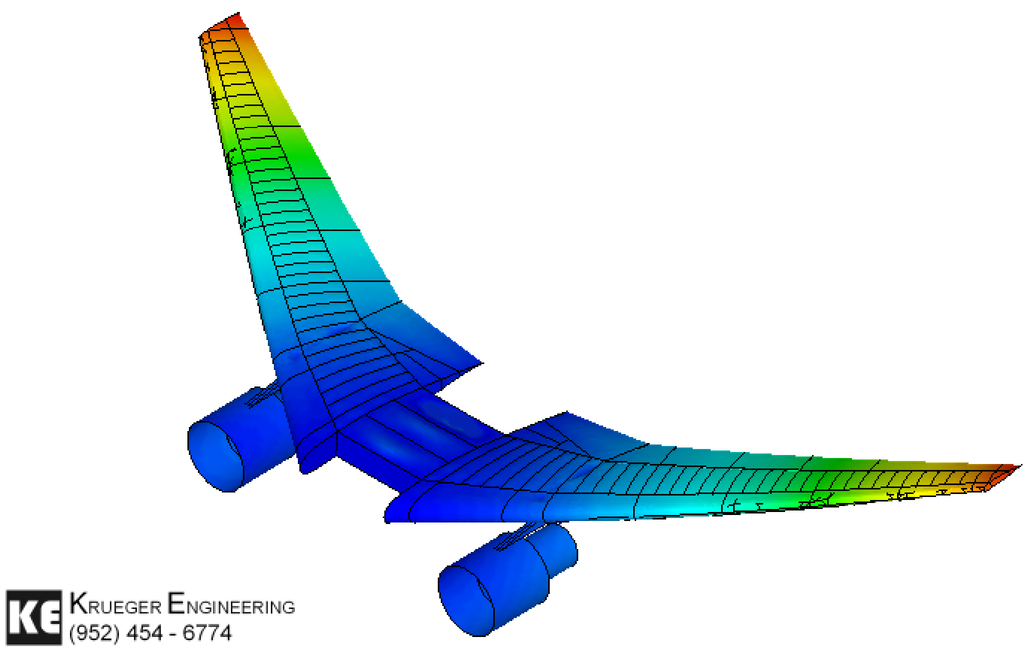



**Figure 2**: **Force distribution on the deflected wing simulated by finite element methods.**