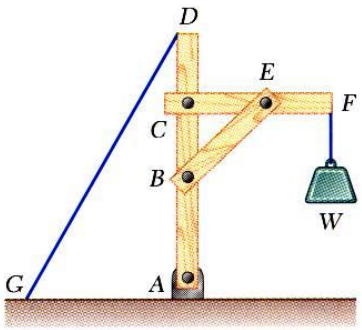
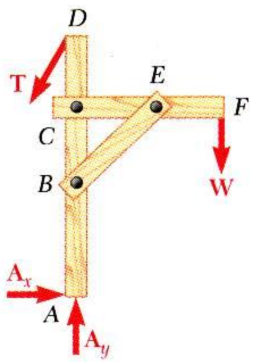
Lecture 12 Frames and Machine

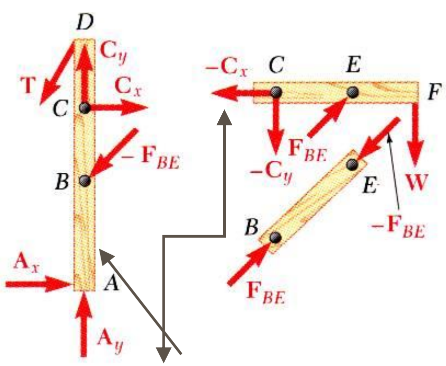
Objective:

Static Analysis of Frames and Machines

12.1 Analysis of Frames







Beam element

- ***Frames*** **are structures with joint connections that connect truss members and at least one *multiforce* member. Frames are designed to support loads and are usually stationary.**
- **Frame has at least one member that can transmit lateral or transverse load and moment.**

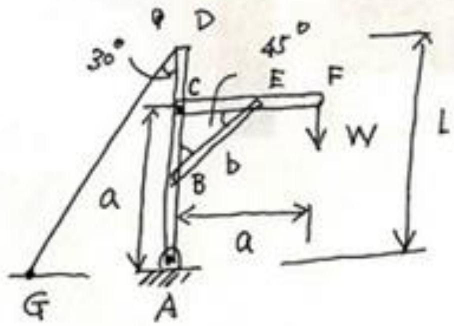
- A free body diagram of the complete frame is used to determine the external forces acting on the frame.
- Internal forces are determined by dismembering the frame and creating free-body diagrams for each component.

- Forces on two force members have known lines of action but unknown magnitude and sense.

- Forces on multiforce members have unknown magnitude and line of action. They must be represented with two unknown components.

- Forces between connected components are equal, have the same line of action, and opposite sense.

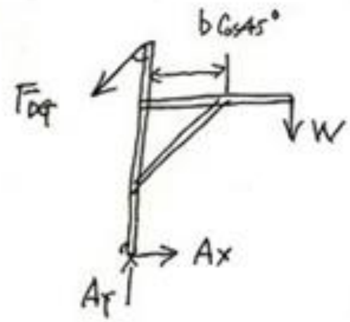
Example :



Find the reactions at A, tensile force in cable DG, and interactions at joints B, C, and E.

[Solution]

① Step 1 Draw free-body diagram of the whole system



$\Sigma M_A = 0$ ↺+

$$-aW + l \sin 30° F_{DG} = 0$$

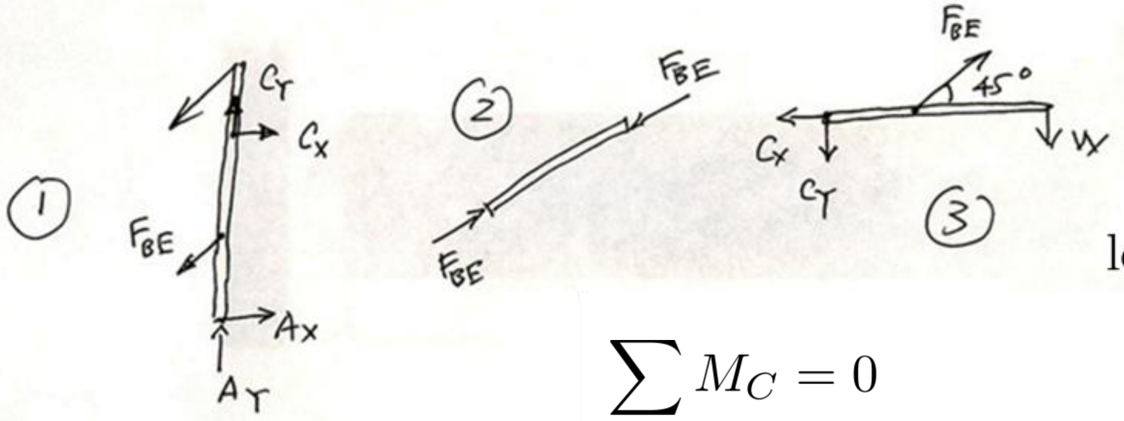
$$F_{DG} = \frac{aW}{l \sin 30°} = \frac{2aW}{l}$$

$\Sigma F_x = 0$ $\quad A_x - F_{DG} \sin 30° = 0 \Rightarrow A_x = F_{DG} \sin 30° = \frac{a}{l} W$

$\Sigma F_Y = 0$ $\quad -F_{DG} \cos 30° + A_Y - W = 0 \Rightarrow A_Y = W + \frac{\cos 30° \, aW}{l \sin 30°}$

$$= W \left(1 + \frac{a}{l} \cot 30° \right)$$

Step 2 Dismember the frame, and draw free-body diagrams of each member.



locate the two-force member

$$\sum M_C = 0$$

$$(b\cos 45^o)F_{BE}\sin 45^o - aW = 0 \;\rightarrow\; F_{BE} = \frac{aW}{(b/2)} = \frac{2aW}{b}$$

$$\sum F_x = 0, \;\rightarrow\; -C_x + F_{BE}\cos 45^o = 0 \;\rightarrow\; C_x = F_{BE}\cos 45^o = \frac{\sqrt{2}aW}{b}$$

$$\sum F_y = 0, \;\rightarrow\; -C_y + F_{BE}\sin 45^o - W = 0$$

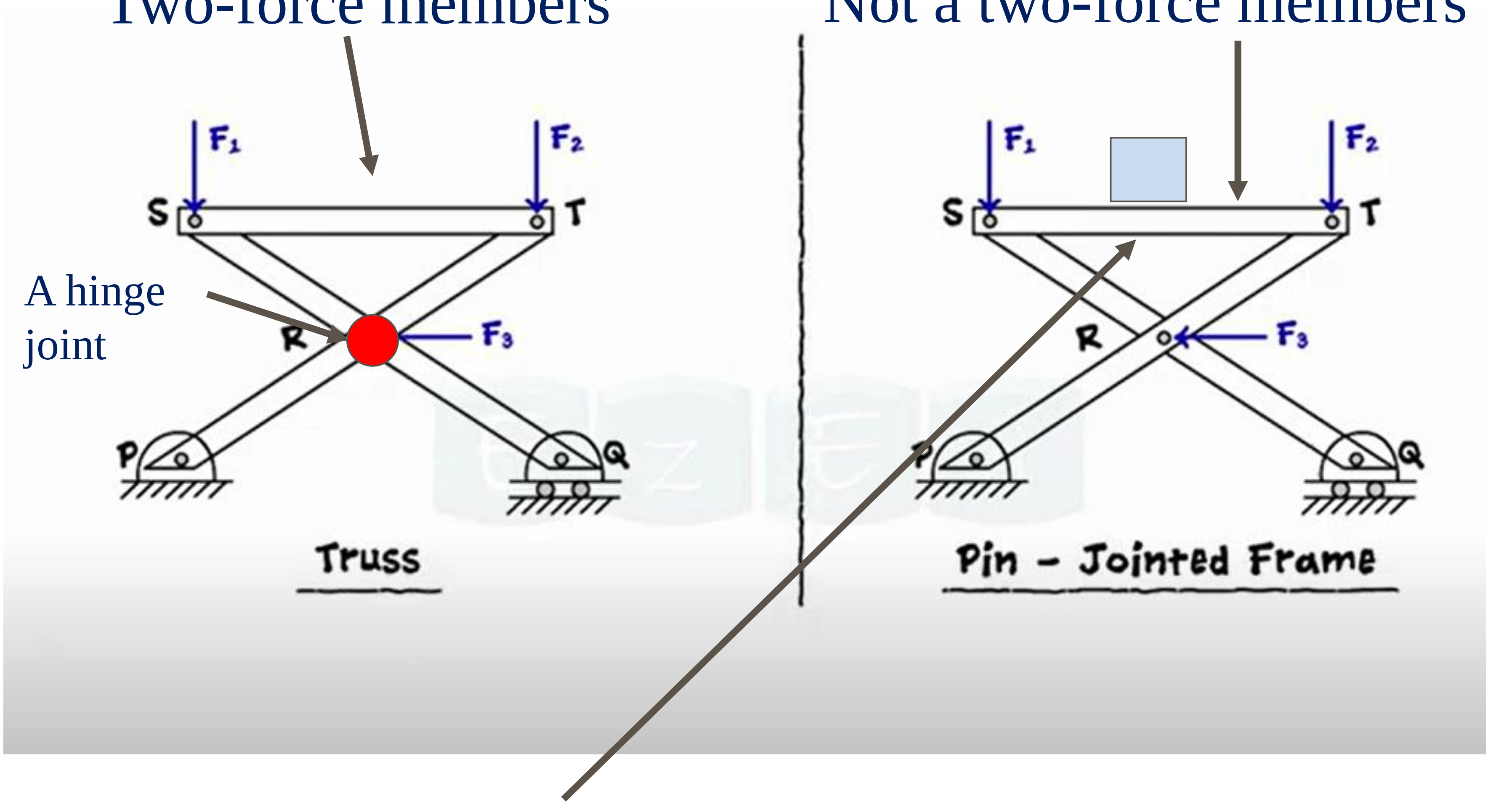
$$\rightarrow\; C_y = F_{BE}\sin 45^o - W = W\left(\frac{\sqrt{2}a}{b} - 1\right)$$

Pin-joined Frame

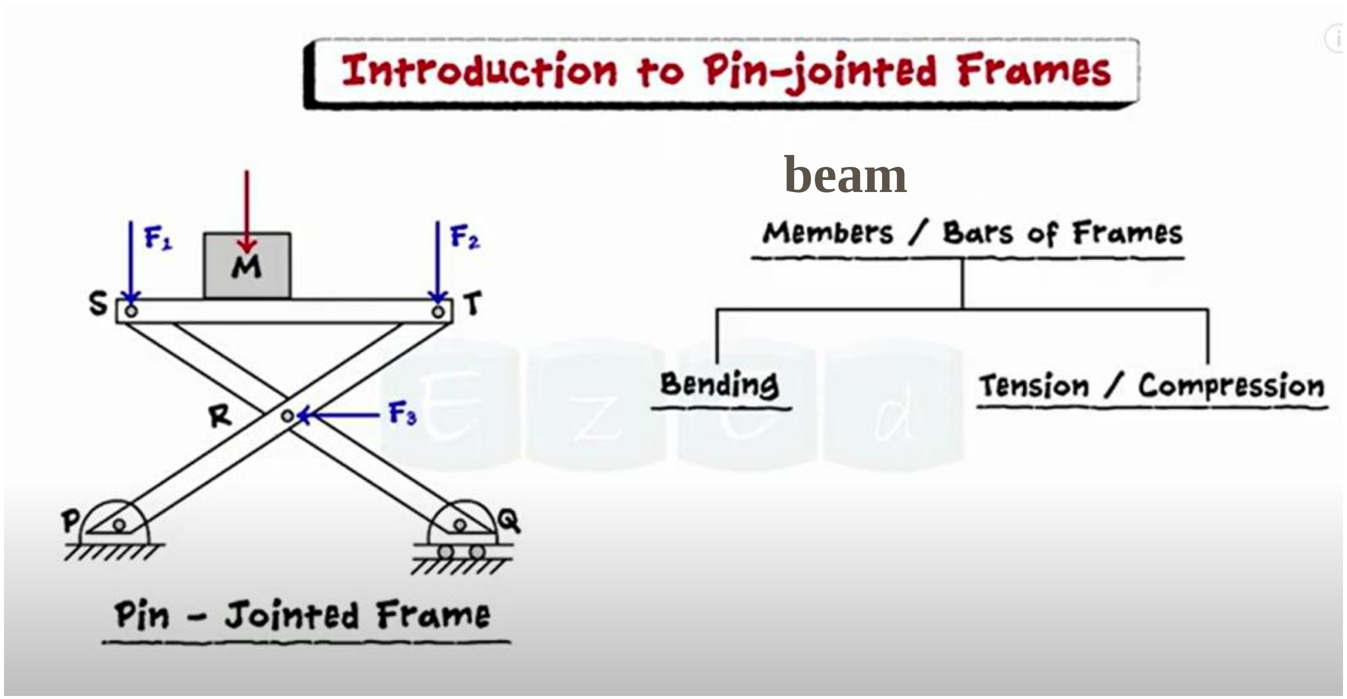
Two-force members

Not a two-force members

A hinge
joint



Transverse force and bending moment


Introduction to Pin-jointed Frames
Members / Bars of Frames
Bending
Tension / Compression
F1
F2
M
S
T
R
F3
P
Q
Pin - Jointed Frame

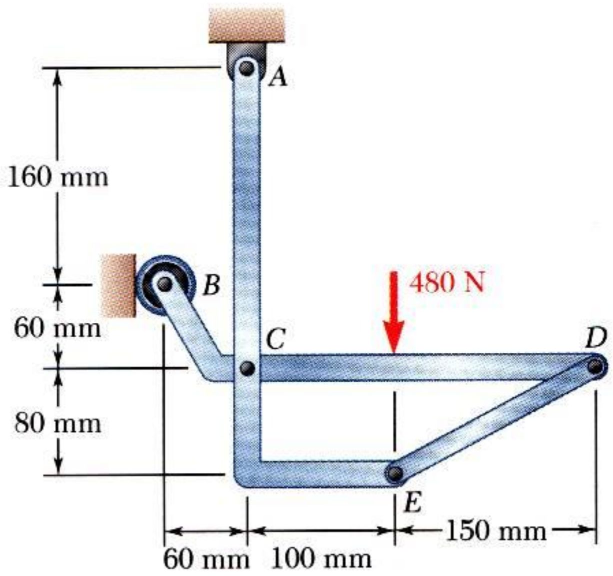
beam

Summary

1. Draw the free-body diagram of the entire frame;
2. Dismember the frame, and draw free-body diagrams for all members;
3. Consider the two-force member first;
4. Consider the multi-force members that are next to a two-force member;
5. When set-up the moment equation, select the point such that the equation involves only one known.

Today's Lecture Password is: Frame

Sample Problem 6.4

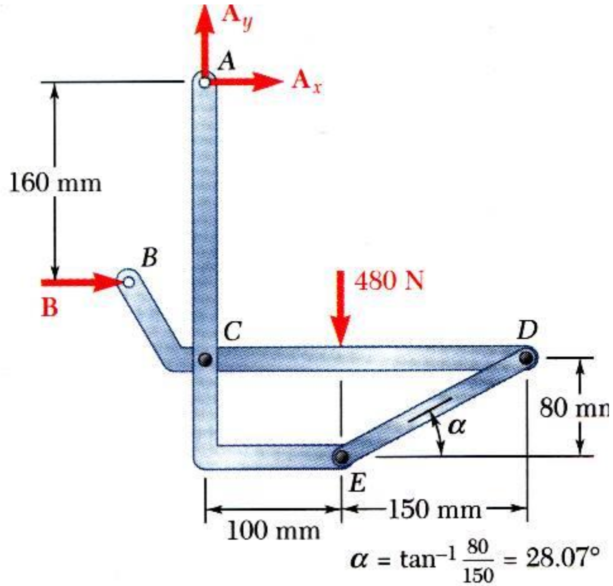


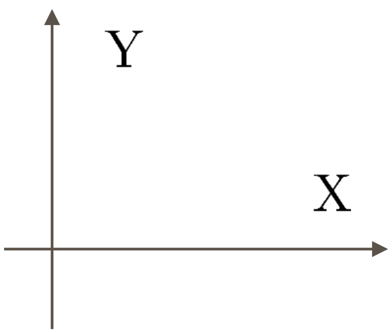
Members *ACE* and *BCD* are connected by a pin at *C* and by the link *DE*. For the loading shown, determine the force in link *DE* and the components of the force exerted at *C* on member *BCD*.

SOLUTION:

- Create a free-body diagram for the complete frame and solve for the support reactions.
- Define a free-body diagram for member *BCD*. The force exerted by the link *DE* has a known line of action but unknown magnitude. It is determined by summing moments about *C*.
- With the force on the link *DE* known, the sum of forces in the *x* and *y* directions may be used to find the force components at *C*.
- With member *ACE* as a free-body, check the solution by summing moments about *A*.

Step I. Global free-body diagram & Reactions





SOLUTION:

- Create a free-body diagram for the complete frame and solve for the support reactions.

$$\sum F_y = 0 = A_y - 480\ \text{N}$$

$$\boxed{A_y = 480\ \text{N}\ \uparrow}$$

$$\sum M_A = 0 = -(480\ \text{N})(100\ \text{mm}) + B(160\ \text{mm})$$

$$\boxed{B = 300\ \text{N}\ \rightarrow}$$

$$\sum F_x = 0 = B + A_x$$

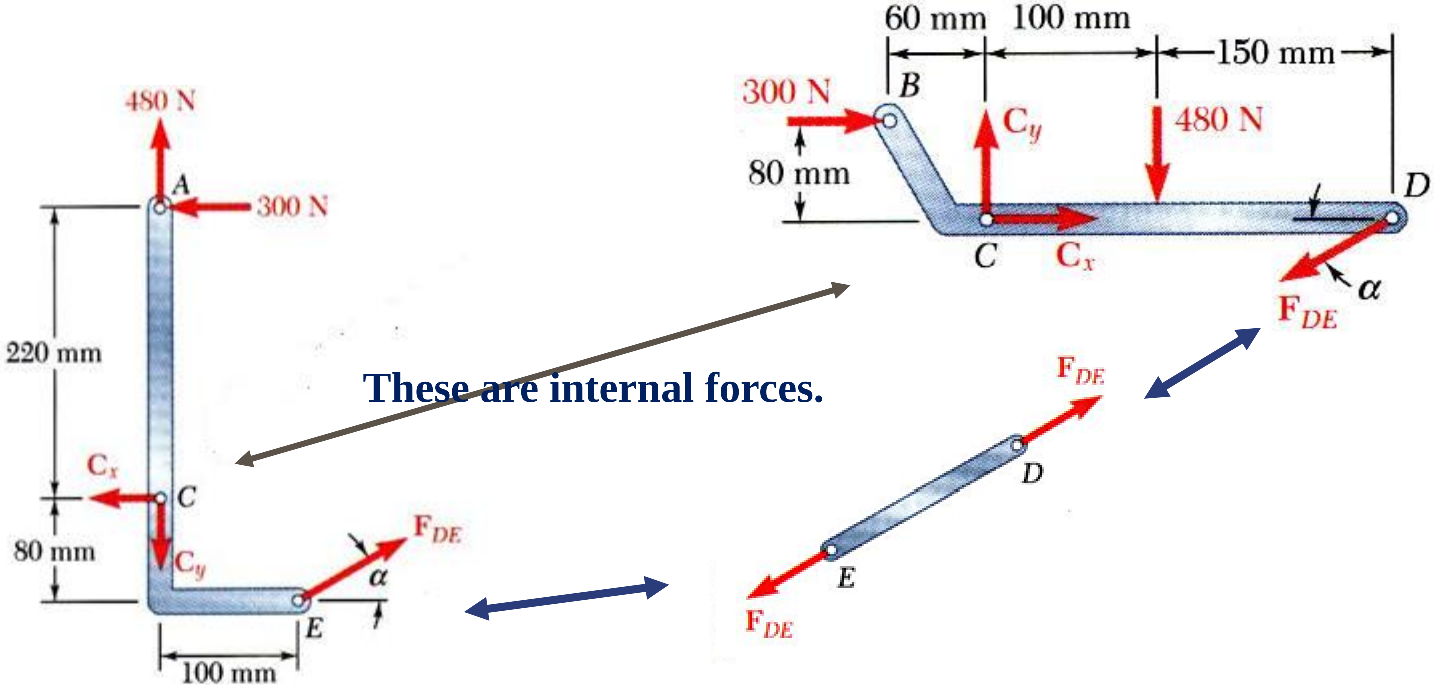
$$A_x = -B = -300N$$

$$\boxed{A_x = -300\ \text{N}\ \leftarrow}$$

Note:

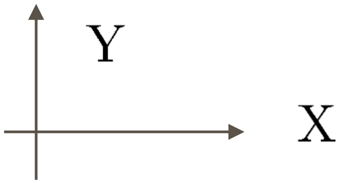
$$\alpha = \tan^{-1}\frac{80}{150} = 28.07°$$

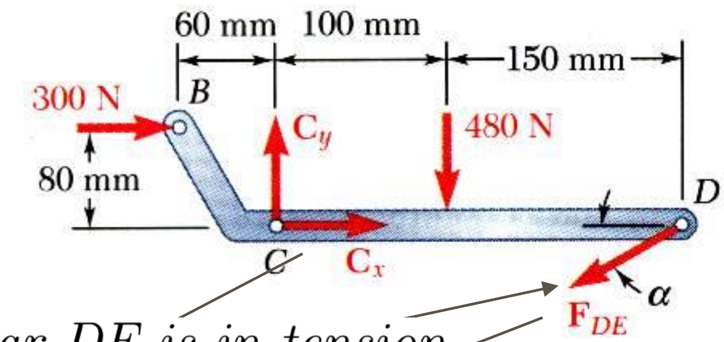
Step 2 Dismember the structure



Draw Free-body Diagram for each member

The direction of F_{DE} comes from the direction of the internal force of the bar DE.





Assume bar DE is in tension.

$$\sum M_C = 0 = (F_{DE}\sin\alpha)(250\text{ mm}) + (300\text{ N})(80\text{ mm}) + (480\text{ N})(100\text{ mm})$$

$$F_{DE} = -561\text{ N}$$

$$\boxed{F_{DE} = 561\text{ N } C}$$

- Sum of forces in the *x* and *y* directions may be used to find the force components at *C*.

$$\sum F_x = 0 = C_x - F_{DE}\cos\alpha + 300\text{ N}$$

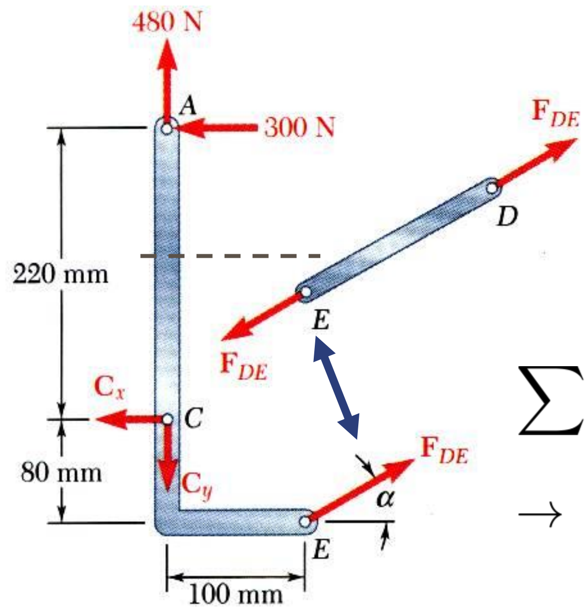
$$0 = C_x - (-561\text{ N})\cos\alpha + 300\text{ N}$$

$$\boxed{C_x = -795\text{ N}}$$

$$\sum F_y = 0 = C_y - F_{DE}\sin\alpha - 480\text{ N}$$

$$0 = C_y - (-561\text{ N})\sin\alpha - 480\text{ N}$$

$$\boxed{C_y = 216\text{ N}}$$



- With member *ACE* as a free-body, check the solution by summing moments about *A*.

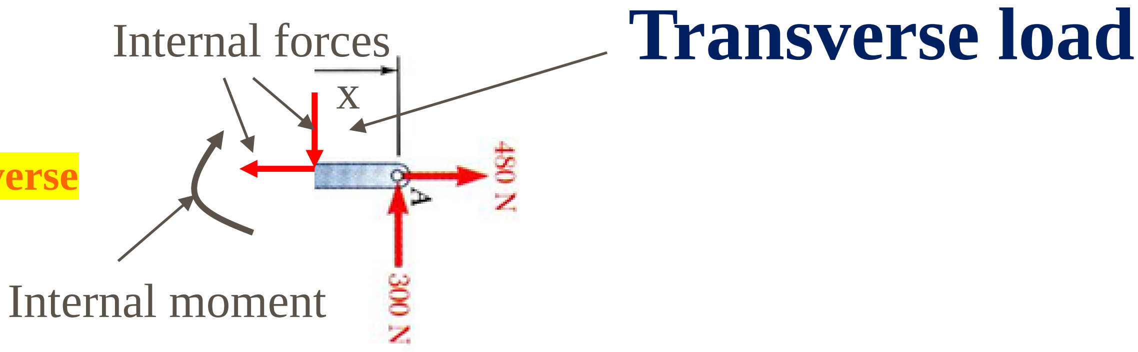
(checks)

$$\sum M_A = 300(F_{DE}\cos\alpha) + 100(F_{DE}\sin\alpha) - 220C_x = 0$$

$$\rightarrow\ 300(-561\cos\alpha) + 100(-561\sin\alpha) - 220(-795) \equiv 0$$

Question: What is the internal force in ACE ?

Frame has at least one member that can transmit lateral or transverse •load and moment.



2. Machines

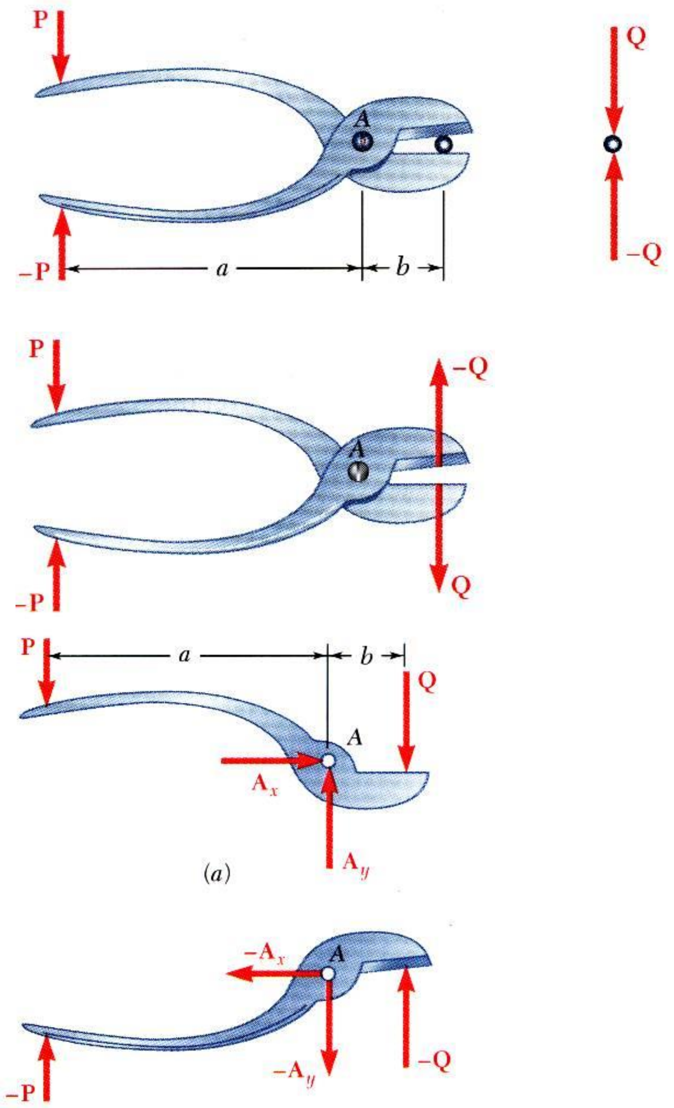
Machines are structures designed to transmit and modify forces, and their main purpose is to transform input force or moment Into desirable output force or moment. Therefore, a machine may or may not be stationary and will always contain moving parts.

The main difference between the frame and the machine is that machines **are not rigid structures ----** they are involved with motion. Nevertheless, in this class, we do not study the dynamics of machines, and we only consider the static equilibrium analysis of the machine.

All machines are improperly constrained!
However, they are usually not trusses.

Machines

The machine is a non-rigid structure.



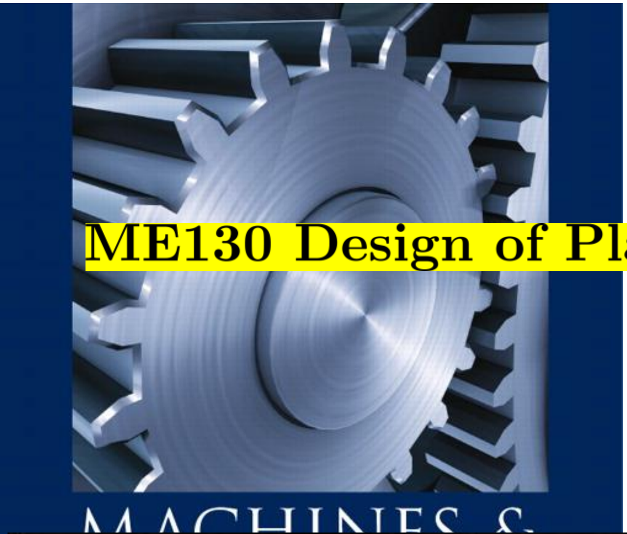
- Machines are structures designed to transmit and modify forces. Their main purpose is to transform *input forces* into *output forces*.
- Given the magnitude of $\boldsymbol{P}$, determine the magnitude of $\boldsymbol{Q}$.
- Create a free-body diagram of the complete machine, including the reaction that the wire exerts.
- The machine is a nonrigid structure. Use one of the components as a free-body.
- Taking moments about A,

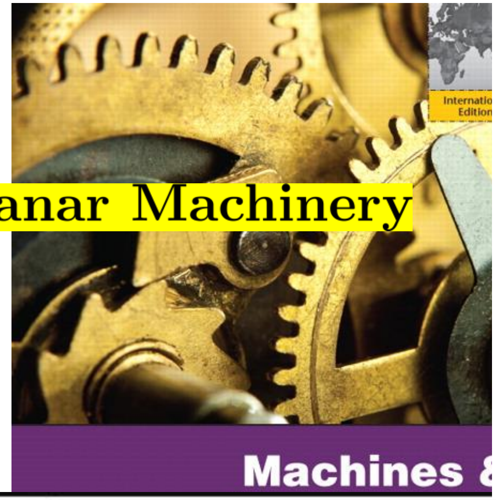
$$\sum M_A = 0 = aP - bQ \qquad Q = \frac{a}{b} P$$

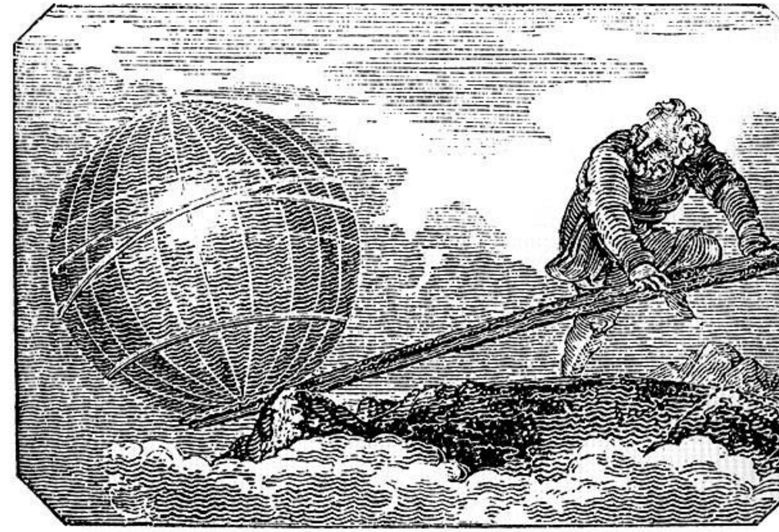
Summary

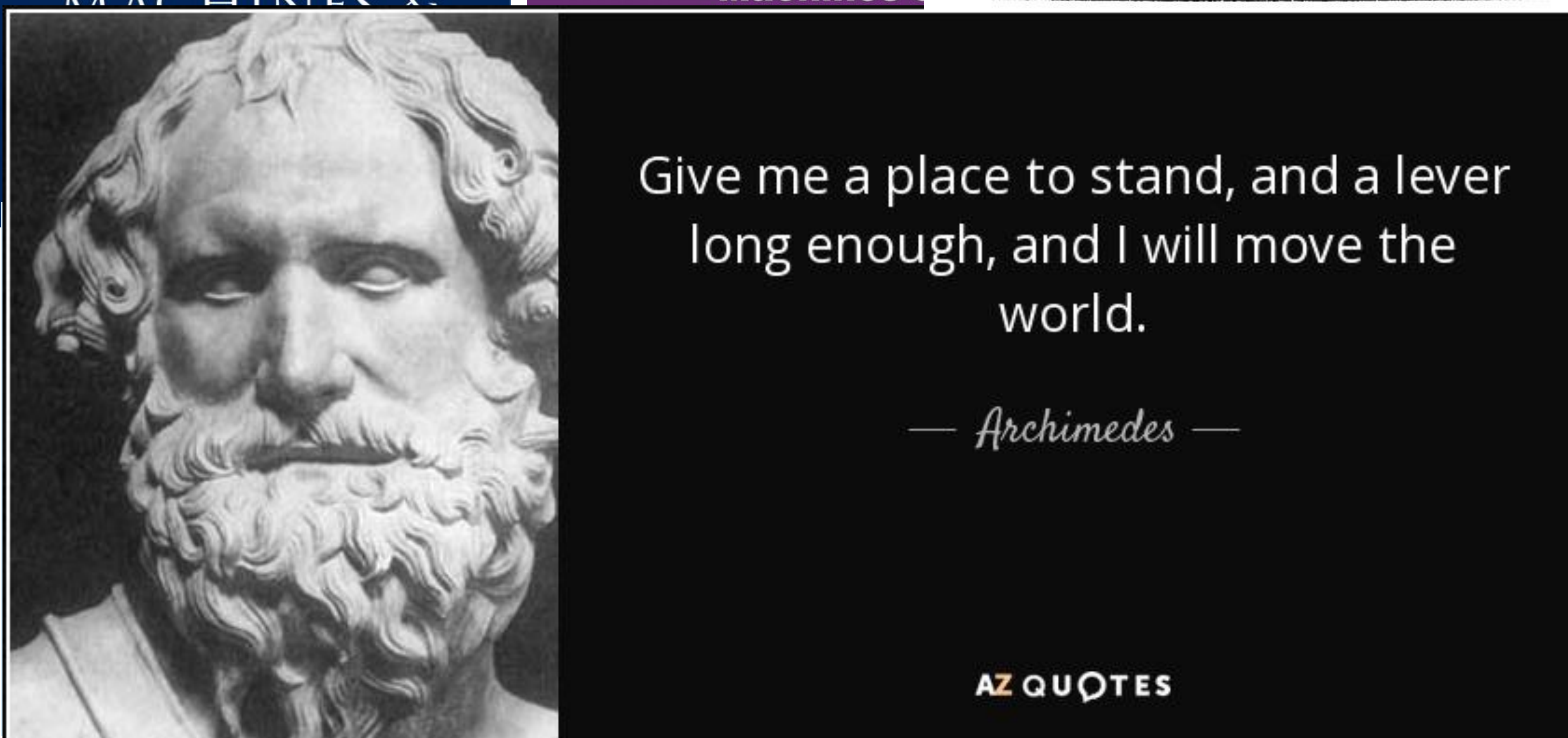
1. Draw the free-body diagram of the whole machine, if necessary;
2. Dismember the machine and draw a free-body diagram for each member;
3. Find the two-force member first;
4. Consider the multi-force member where a force may be prescribed or it is connected to a two-force member;
5. Select the point where the moment equation only contains one unknown;
6. Check your answer.

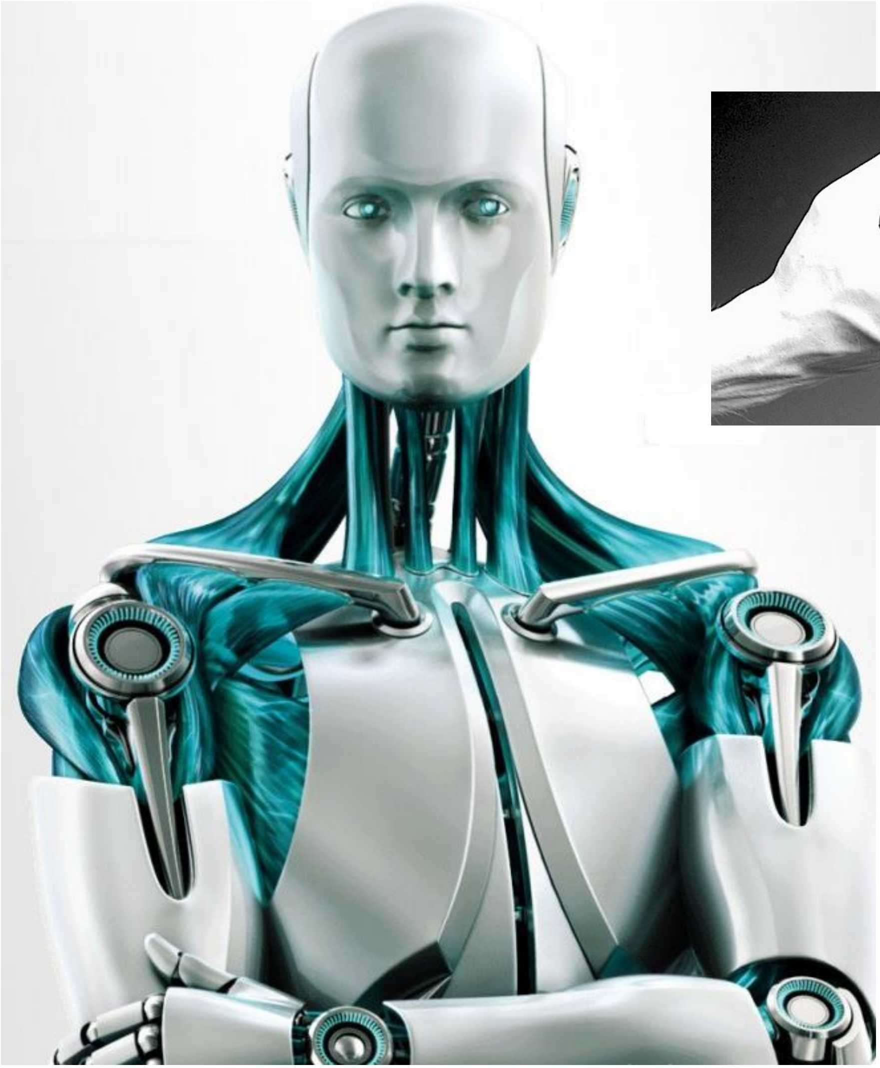
ME130 Design of Planar Machinery

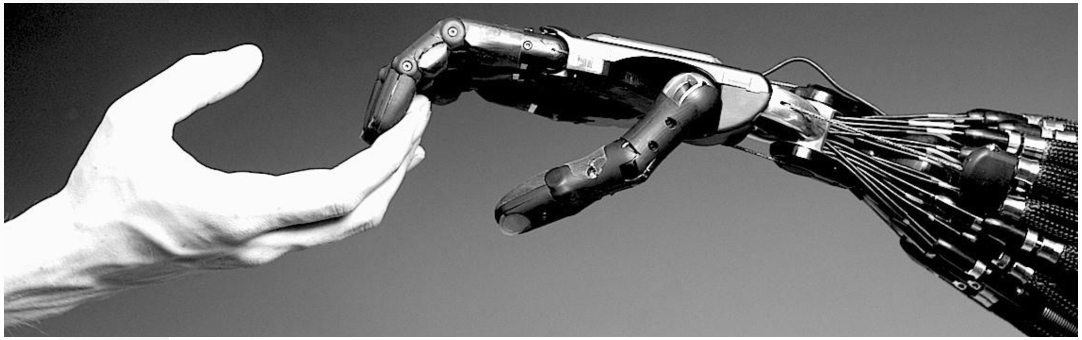








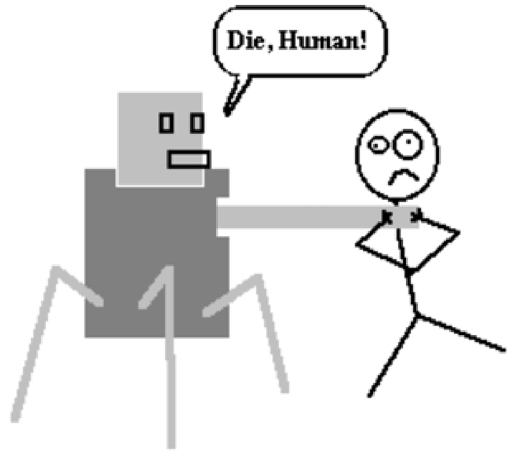


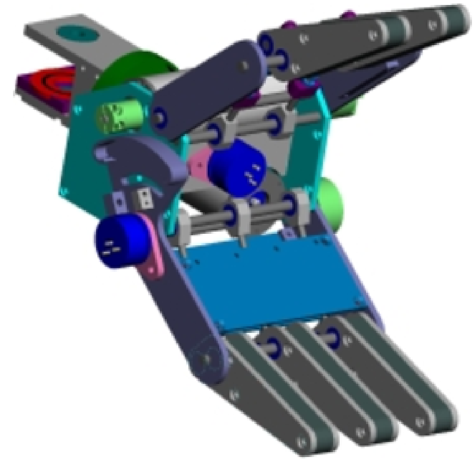


Machine is a really cool thing !

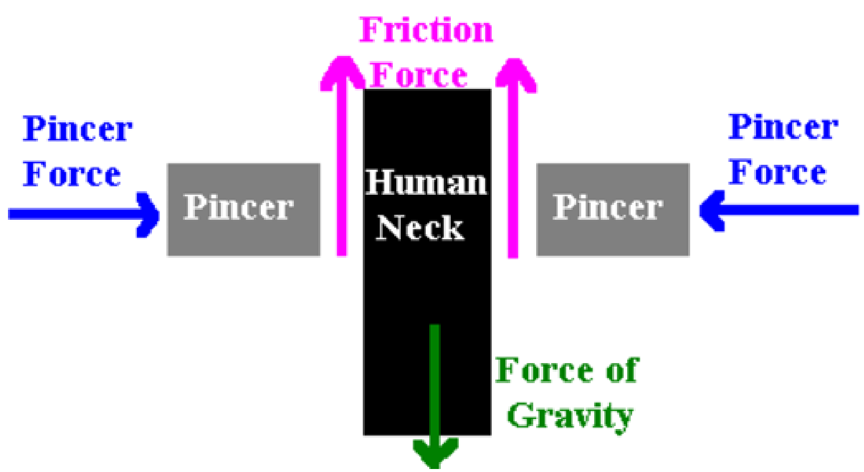
Robot Statics:

From Society of Robots

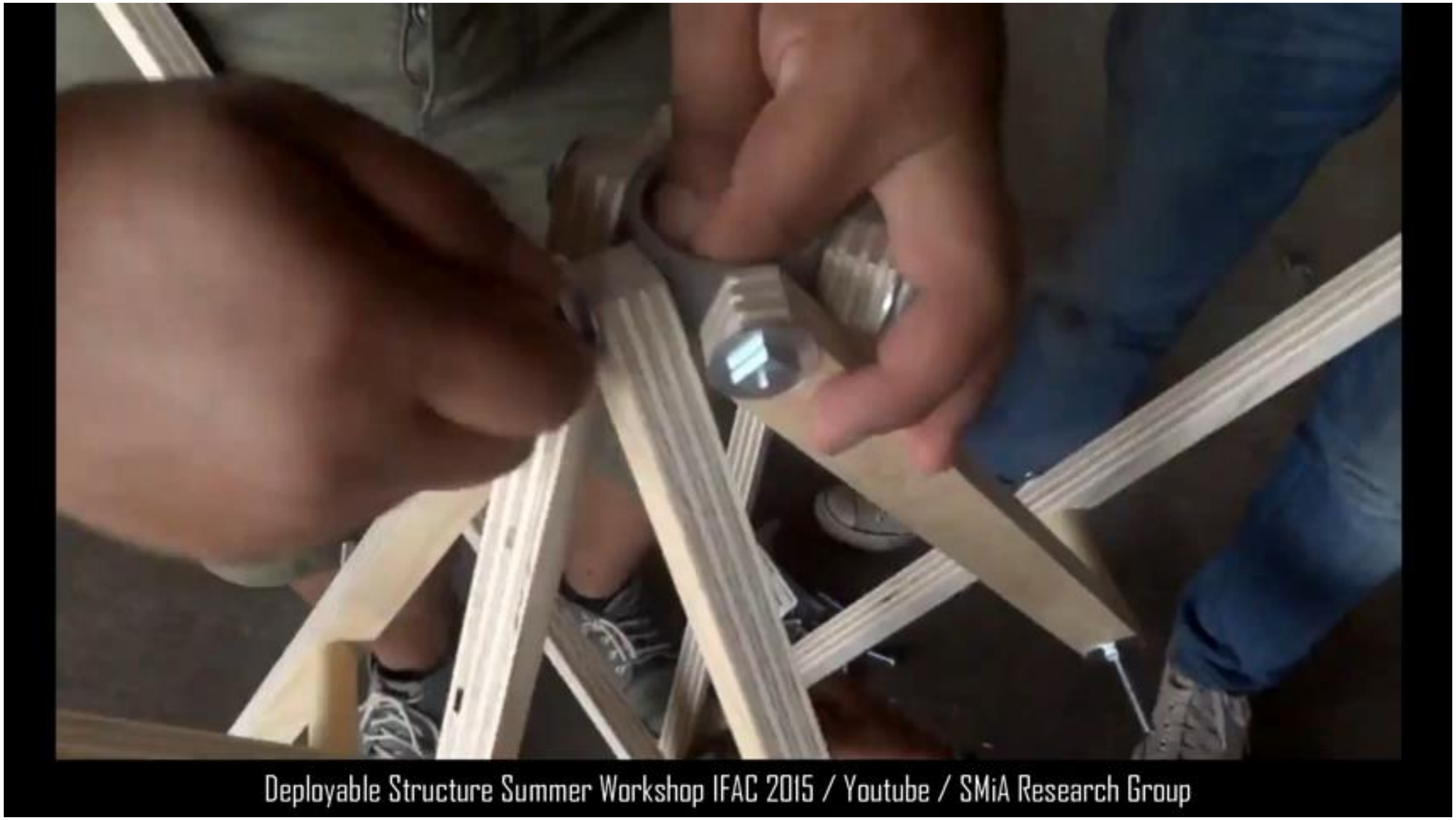




Understanding friction is also useful when designing **robot pincers**. If the friction is miscalculated, your robot victims would be able to escape! Now we cant have that . . . So here is how you do it. A robot pincer squeezes from both sides. So this is your force. The typical human however wants to fall down out of your robot pincers by gravity.



Now all you need to do is squeeze hard enough so that the force of friction is greater than the force of gravity.



Origami Structures