MEEG3311 Machine Design

Lecture 1: Intro To Design;
Units; FBDs; Stress &
Mohr's Circle

W Dornfeld
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Fairfield University
School of Engineering

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What's Machine Design all about?

"Design" is used to refer to lots of different activities, but relating to engineering, it usually means one of two things:

1. Industrial Design
   = Applied Art; concerns asthetics, ergonomics, useability
2. Machine Design
   = Creating the mechanisms and structures to perform a function.

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Design Phases/Activities

Starts with "*Someone needing something to do some function*"
The "something" is the machine.

A. Deciding

- » Requirements
- » Concepts
- » Constraints
- » Back Of Envelope Calcs
- » Components
- » Materials
- » Appearance
- » Patents / Standards

B. Sizing

- » Strength
- » Life
- » Appearance
- » Dimensions (Overall & Parts)
- » Detailed Analysis
- » Cost
- » Factor of Safety

C. Realizing

- » Drawings
- » Configuration
- » Finishes
- » Manufacturing
- » Tolerances
- » Support / Repair

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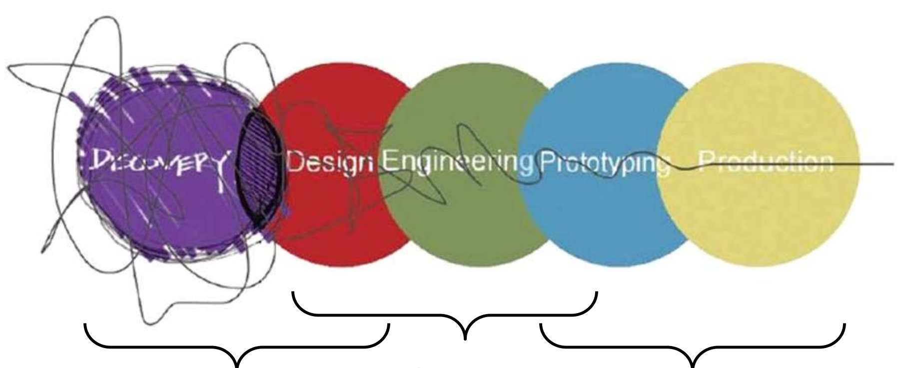
Design Phases/Activities



Deciding

Sizing

Realizing

http://www.phillipsplastics.com/case_studies

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Design Classifications

A. Integrated Design
= Use “Off the Shelf” components (catalog items; standard structural shapes; etc.) to build a mechanism.
Ex: Popular Mechanics-like things; Processing equipment

B. Custom Design
= Totally unique, self-designed components and structure
Ex: Automobiles; consumer products; leading-edge technology

C. Mixed Design
= Vendors slightly modify their parts
Ex: Medium production items; Agricultural equipment

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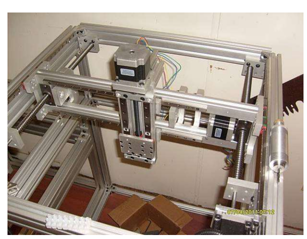
Examples of Integrated Design

http://misumiusa.com/technical/techSeminar.aspx

http://develop3d.com/images/articles_fullwidth/Chaise_longue_FW.jpg

http://diydrones.com/profile/JeffZika



http://www.acomputerportal.com/3D_printers.html

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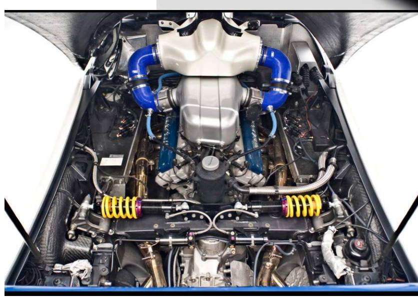
Example of Custom Design



http://www.seriouswheels.com/mno/Maserati-MC12-Studio-FA-Top-Off-1280x960.htm

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Examples of Mixed Design

http://www.atomiczombie.com/StreetFoxSuspensionTadpoleTrike.aspx

http://www.stanneconsignmentauction.net/photos/06190953.JPG

http://hamptonroads.com.nyud.net/node/251081

http://www.tjsnow.com/special.htm

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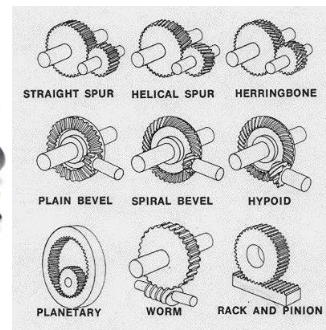
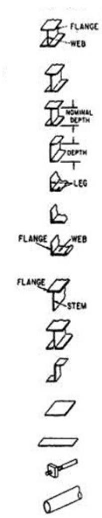
Design Components





- McMaster-Carr
- Grainger
- Misumi

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More Design Components

- Motors
- Flywheels
- Hydraulics
- Pneumatics
- Pulleys & Belts & Chains
- Brakes & Clutches
- Etc…

To use any of these components, you need to know:

1. That they exist,
2. How they work, and
3. How to “size” them for your application.

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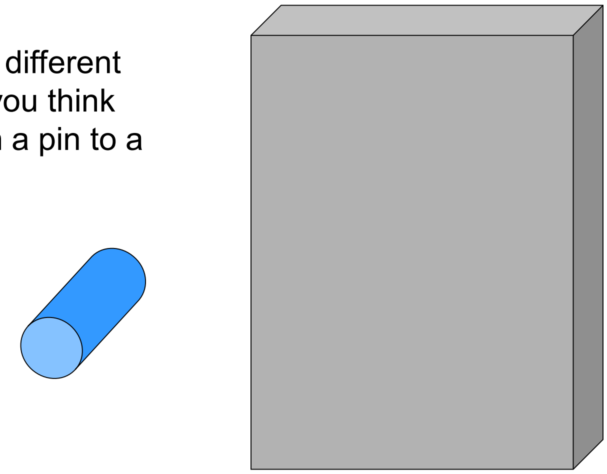
Design Concept Activity

How many different ways can you think of to attach a pin to a plate?



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Design Requirements

A. Function
= The device must perform the duty for which it is intended.

B. Durability
= The device must operate without failing for the intended lifetime.

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MEEG3311 Philosophy

Learn the Building Blocks of Design

(not a lot of synthesis, but at least some of the ingredients)

> **Free Body Diagrams** – because if you get the loads wrong, the stress and deflection analyses will be wrong.
> **Simple Analyses** – most everything will be considered a beam; you must keep your FEA honest and know how design parameters affect the strength.
> **Failure Mechanisms** – learn them so you can avoid them.
> **Mechanical Components** – what is available, how do they work and break?

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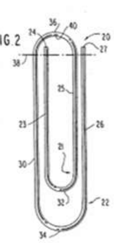
Failure Modes

- Yield
- Fracture – Elastic and Brittle
- Excess deflection
- Buckling
- Fatigue
- Wear
- Corrosion

FIG 2



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Techniques

- **Analyzing real hardware (not lab stuff) and recognizing assumptions via the Reverse Engineering project.**
- **Mistake Reduction**
  > Drawing sketches with accurate proportions
  > Making correct FBDs
  > Showing your intermediate calculations (not just calculator =)
  > Automating analyses with Excel, MathCad, Matlab, etc.
  > Showing and checking units
  > Asking "Does that make sense?"
- **Use the Web**
  > Tutorials and solved problems
- **Build confidence level**
  > Read the practice problems; do the homework

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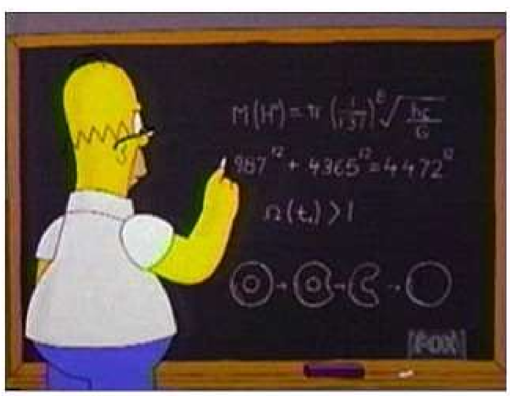
NOT MEEG3311 Philosophy

"I Don't Want To Learn...Just Give Me The Answers!"



 I don't want your answers; I want to see you learn how to get them.

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Academic Honesty

Basically, if you submit something that is someone else's work (whether it is a classmate, a friend, or from the Web) and do not reference the source, that is academically dishonest.

Collaboration in the learning of this material is encouraged, and that applies to discussions of homework and of assigned team projects. But if you complete your homework, and in discussion with a colleague discover an error which you then correct (but not by copying from the colleague), you should state that you corrected it.

Class exams are intended to represent your individual work. It is dishonest to get help from other students or anyone else, including Chegg.

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Catch 22

Two requirements to be an engineer:

1. Knowledge of technical subjects
2. Ethical behavior

Two characteristics of people who would cheat on an exam:

1. ___________________ (Don't know the material)
2. ___________________ (Lack of Ethics)

Conclusion:

If you find that you can't learn this material and that you do not possess enough personal honesty or integrity to be an engineer, then you need to transfer to some other field of study. The sooner, the better.

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Homework

If you can do the homework, you will be successful in doing the MEEG3311 exams.

The homework problems used in MEEG3311 are not from the Hamrock textbook.

Repeated instances of students copying and submitting homework solutions found on the internet (faithfully copying errors and all) and then not understanding the material on the exams, made this necessary.

There will be hints and some answers posted on the course web site to help you out if you get stuck.

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How to ~~survive~~ succeed at MEEG3311

1. Read the material for each week <u>before</u> class.
2. Then the examples and activities we do in class will make sense.
3. Do the homework first without hints or solutions.
4. Ask questions if you don't understand something.
5. Work the in-class problems.

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Units

	English	Metric
Mass f=ma; w=mg; m=w/g	$\frac{1 lb_f}{386.4 in/s^2}$	1kg = 2.205 lb_m (1g = 9.807 m/s²)
Length	1 in. = 25.4mm	1m = 39.37 in.
Force	1lb_f = 4.448N	1N = 0.2248lb_f $= 1kg \times 1 m/s^2$ 
Pressure (or Stress) = $Force/Area$	1 psi = 6894.8Pa = 6.9 kPa 1 ksi = 6.9 MPa	$1Pa = 1\frac{N}{m^2} \approx \frac{0.25lb}{1600in^2}$ $1MPa = 1\frac{N}{mm^2} = \frac{1{,}000{,}000 Pa}{6894.8 Pa/psi} = 145 psi$ ~10 Atm
Power $= Work/Time$	1HP = 6600 $in.lb/s$ = 745.7 W	1W = 1 Nm/s

So, what does a kilogram weigh?

What is the pressure of a dollar bill?
m = 0.984gram, 66.3mm x 156.0mm

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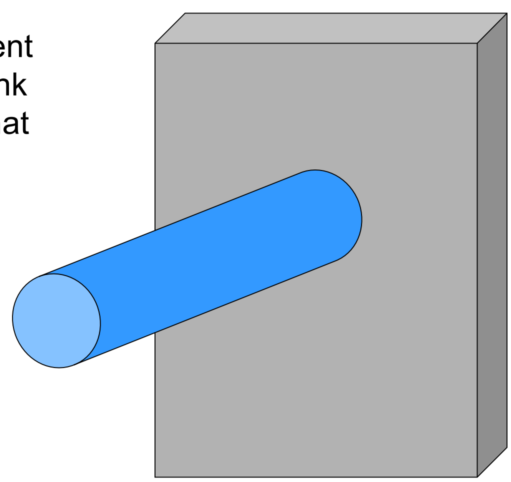
Load Types

How many different ways can you think of to load a pin that is attached to a plate?



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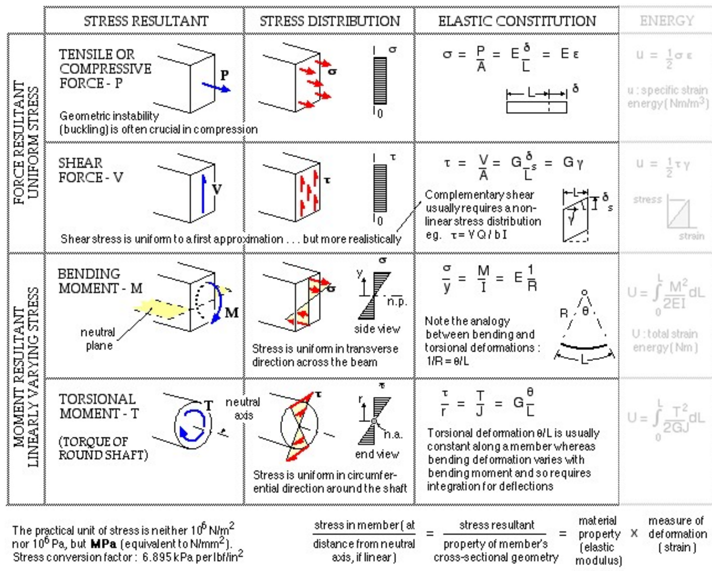
Elementary Load Building Blocks



From DAWright at U of Western Australia

See Hamrock Fig. 2.4

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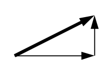
Free Body Diagrams

- Disassemble and/or cut apart
- Draw all known and unknown loads and reactions
- Resolve "skew" Forces into Vertical & Horizontal
- Balance Forces (V & H) and Moments on each piece
- Internal loads on each side of a connection are equal and opposite
- We need Forces and Moments to get stresses and deflections



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Free Body Diagram

Which one of these guys probably doesn't understand Free Body Diagrams?

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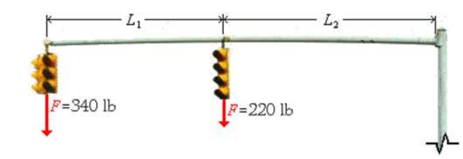
FBD: Traffic Light Pole



L1 = 100 in.   L2 = 120 in.

L1 + L2 = 220 in.

From U of Arkansas FEMur

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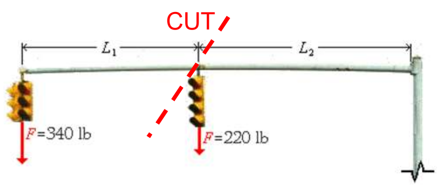
FBD: Traffic Light Pole



L1 = 100 in.   L2 = 120 in.

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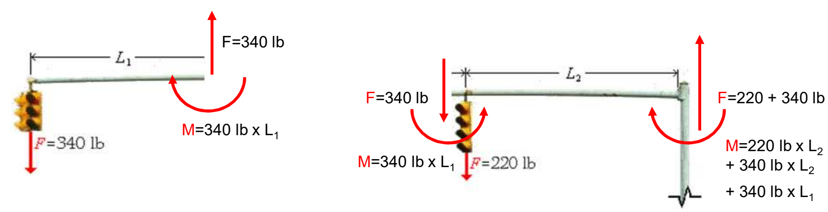

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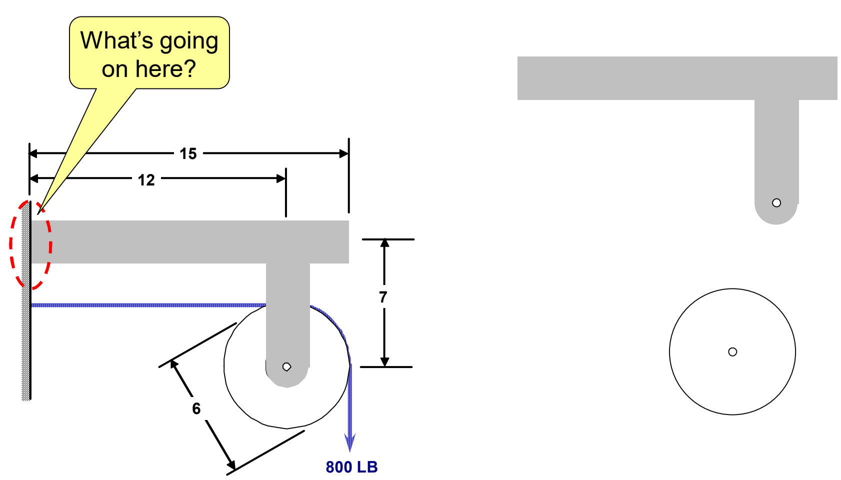
FBD: Pulley On Arm



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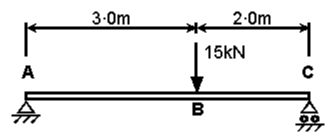
Beam Shear & Moment

Procedure:

Step 1: Compute the reaction forces and moments

Step 2: Break beam into segments

Step 3: Compute shear forces and moments for each piece to be balanced



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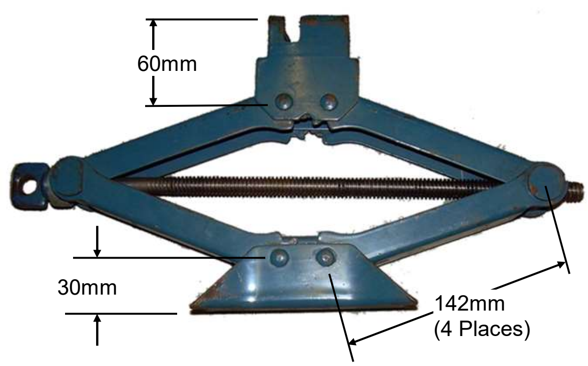
FBD: Car Scissors Jack



Given the information on the next page, determine the load in the screw when the front wheel just lifts off the ground.

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FBD: Car Scissors Jack

2002 VW Cabrio
GVWR* = 3616 LB
Front: 2029 LB
Rear: 1654 LB

With the scissors jack behind a front wheel, the tire will just lift off the ground when the top of the jack is at 9 ¾" = 247.65mm.

At that point, it takes a force of 17LB to turn the handle.

* The gross vehicle weight rating (GVWR) is the maximum allowable total weight of a road vehicle that is loaded, including the weight of the vehicle itself plus fuel, passengers, and cargo.

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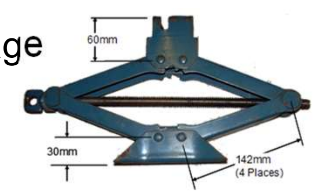
Hints:
1. Disassemble things
2. Write down what you know
3. Balance and solve for what you don't know
4. Carry forces & moments equal and opposite to the next member
5. Resolve angled forces into H and V components

FBD Calculation Page



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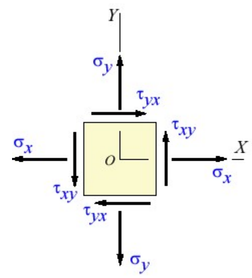
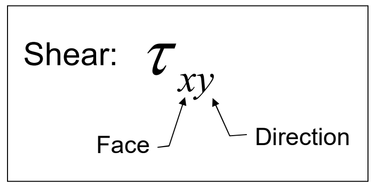
Mohr's Circle

- Combinations of stresses do happen.
- What you see depends on which direction you look.



Note the Equilibrium



Convention: CCW τ_{xy} is Positive

Both Face and Direction are Positive (Same as in Beer & Johnston)

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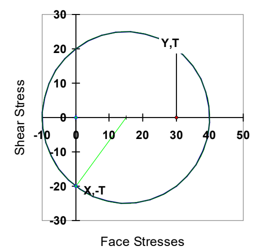
Mohr's Circle



For any element with stresses σ_x, σ_y, τ_{xy}:

A. Plot point "X" at (σ_x, $-\tau_{xy}$)

B. Plot point "Y" at (σ_y, τ_{xy})

C. Calculate the Center at $\left(\frac{\sigma_x+\sigma_y}{2}, 0\right)$

D. Calculate the Radius as $\sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2+\tau_{xy}^2}$

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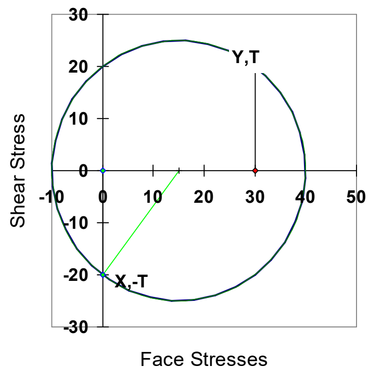
Mohr's Circle

For Xstress = 0.0,
Ystress = 30.0, XYShear = 20.0,
Angle = -63.43°, Stress1 = 40.00,
Stress2 = 0.00, Stress3 = -10.00,
ShearMax = 25.00



σ_x=0, σ_y=30, τ_{xy} =20

A. Plot "X" at (σ_x, -τ_{xy}) = (0, -20)
B. Plot "Y" at (σ_y, τ_{xy}) = (30, 20)
C. Center = ([0+30]/2,0) = (15, 0)
D. Calculate the Radius as Sqrt(15^2 + 20^2) = Sqrt(625) = 25

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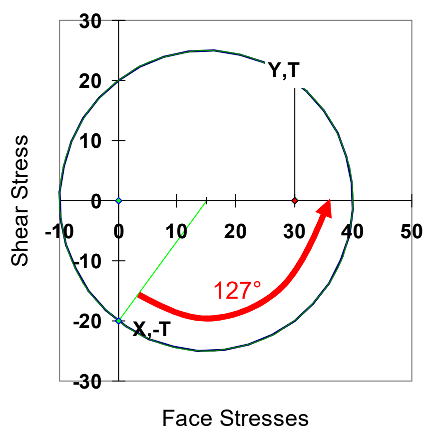
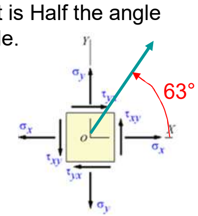
Mohr's Circle



Note: Convention is to rotate "X" point to Max Principal.

Go CW if "X" is in the upper half; CCW if "X" is in the lower half.

This corresponds to the same direction rotation on the Part, but the angle moved on the Part is Half the angle moved on the circle.



Note 2: Circle is always centered on the horizontal axis because shears are always equal and opposite.

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Mohr's Circle

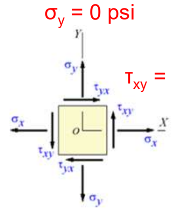
A tensile tester puts a 1000lb load on a 1inch square bar.

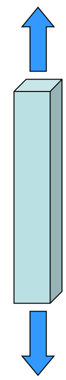
Draw the Mohr's Circle,
Find the principal stresses,
Find the angle to σ_{max}

σ_y = 0 psi

τ_{xy} = 0 psi

σ_x = 1000 psi





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Mohr's Circle

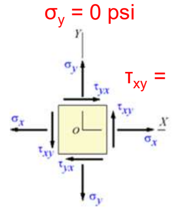
A loaded wrench sees both bending and torsional stress.

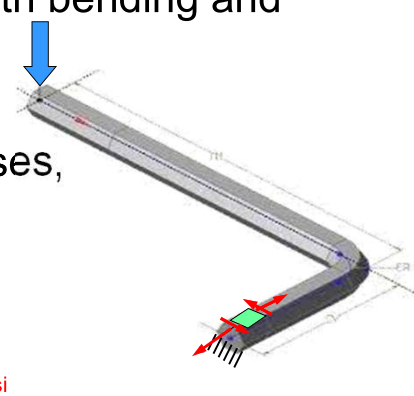
Draw the Mohr's Circle,
Find the principal stresses,
Find the angle to σ_{max}

σ_y = 0 psi

τ_{xy} = 300 psi

σ_x = 1000 psi





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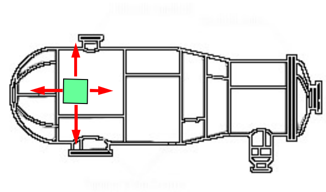
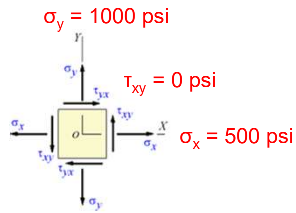
More Mohr's Circle

A pressurized tank sees
bidirectional normal stress.

Draw the Mohr's Circle,
Find the principal stresses,
Find the angle to σ_{max}





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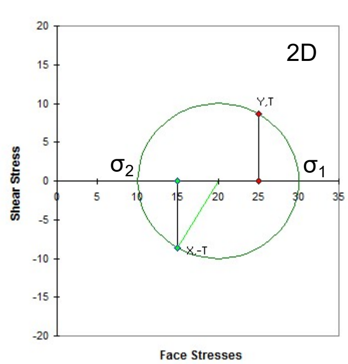
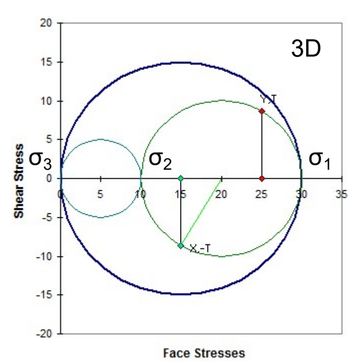
One More Mohr: 3D

If you have a case (like the last slide) with plane stress where σ_1 and σ_2 are <u>either both positive or both negative</u>, you need to include σ_z =0 in drawing a 3D Mohr's Circle.

Consider the case where σ_x = 15, σ_y = 25, and τ_{xy} = 8.66.

We must include σ_z = 0 to not miss the maximum shear stress.





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