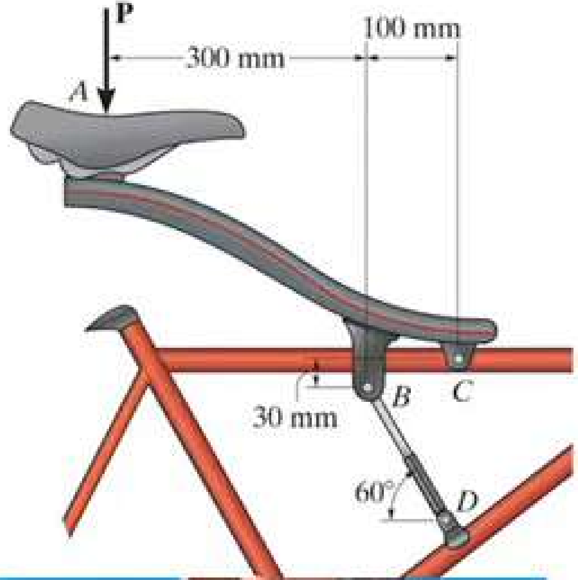
Course Outline

- Part I
  - Review of Material properties
  - Stress analysis
  - Stiffness and deflection analysis
- Part II
  - Failure due to static loads
  - Failure due to dynamic loads
- Part III
  - Analysis, selection and design of mechanical elements, such as fastners, springs, bearings and etc.

Course objective

The objective is to answer either of these

Questions:



- ❑ What is the model and geometry suitable to perform the specific function.
- ❑ For a given geometry, how the component will perform (fail, life).

1.1 Design

Design is:

- ❑ An innovative
- ❑ Highly iterative
- ❑ A decision-making process.

(Choose the best of all solutions)

Product must be:

- Functional
- Safe
- Reliable
- Competitive
- Usable
- Manufacturable
- Comply with codes and standards

Design Consideration

- The importance of these listed points varies from design to design.
- A trade-off is often taken place.

1	Strength	14	Noise
2	Stiffness	15	Styling
3	Wear	16	Shape
4	Corrosion	17	Size
5	Safety	18	Control
6	Reliability	19	Thermal properties
7	Friction	20	Surface
8	Usability	21	Lubrication
9	Utility	22	Marketability
10	Cost	23	Maintenance
11	Processing	24	Volume
12	Weight	25	Liability
13	Life	26	Recovery

1.6 Codes And Standards

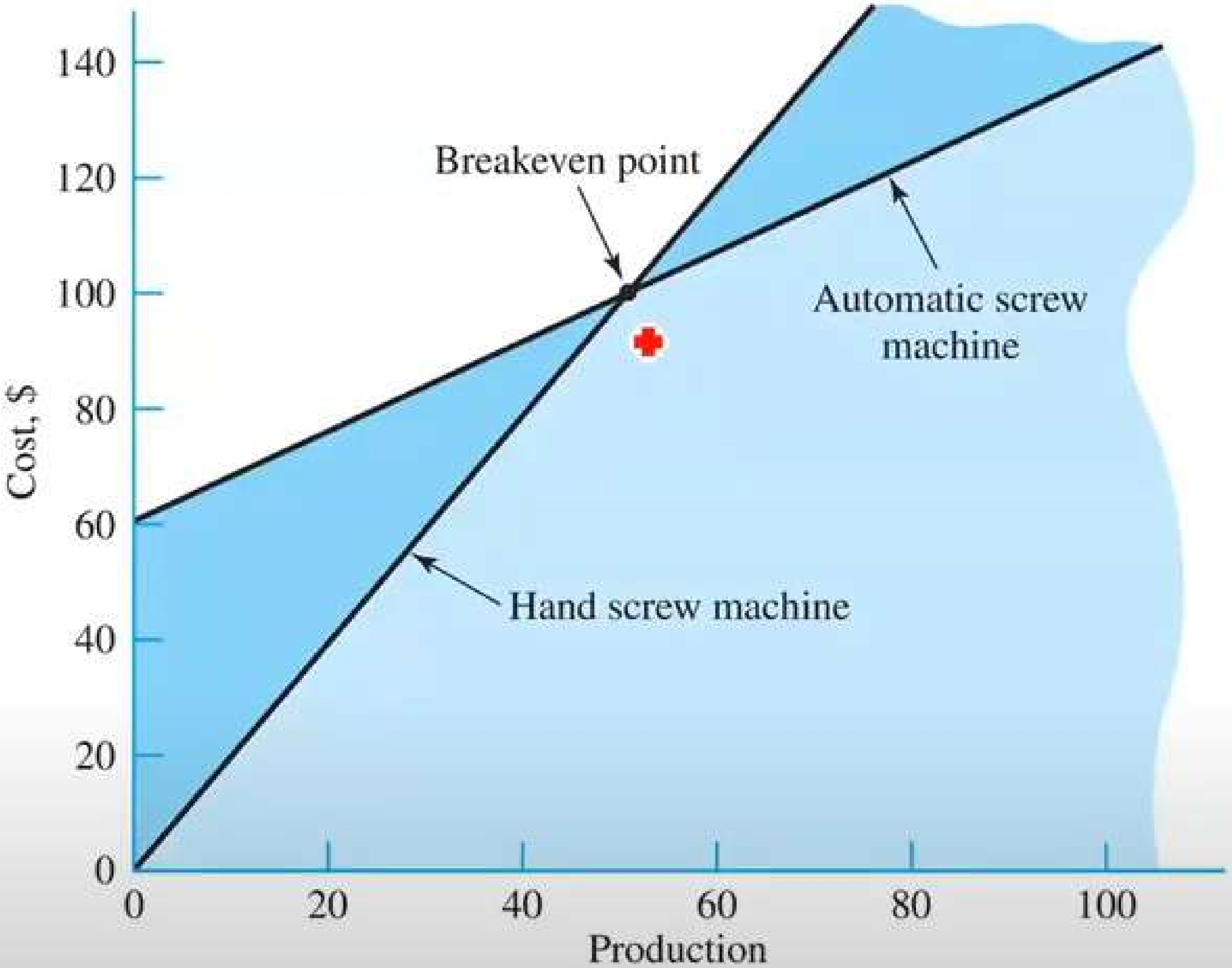
- **Standard**- a set of specifications for parts, materials, or processes.
  - *Provide reasonable inventory of tooling, sizes and shapes*

- **Code- a set of specifications for the analysis, design and manufacture processes.**
  - *Achieve a specific degree of safety, efficiency and quality.*

Organizations

AISC	American Institute of Steel Construction	**ABMA**	American Bearing Manufacturers Association
AA	Aluminum Association	**BSI**	British Standards Institute
AGMA	American Gear Manufacturers Association	**IFI**	Industrial Fasteners Institute
AISI	American Iron and Steel Institute	**I. Mech. E.**	Institution of Mechanical Engineers
ANSI	American National Standards Institute	**BIPM**	International Bureau of Weights and Measures
ASM	American Society for Metals	**ISO**	International Standards Organization
ASME	American Society of Mechanical Engineers	**NIST**	National Institute for Standards and Technology
ASTM	American Society of Testing Materials	**SAE**	Society of Automotive Engineers
AWS	American Welding Society	**ASABE**	American Society of Agricultural and Biological Engineers

Breakeven Points



above 50 part, use automatic machine.

1.11 Design Factors and Factor of Safety

- **Ratio of two quantities with the same units**
  - Strength/stress
  - Critical load/applied load
  - Maximum number of cycles/applied number of cycles
- **Form is based on expected mode of failure**
  - By yield, strength/stress
  - By buckling, critical load/applied load
- **May have several factors of safety; one for each different type of failure possible**

  Choose the smallest of these factors

1.15 Units And Preferred Units

SI UNITS

Base units

- Mass M (kg).
- Length L (m).
- Time T (s).

Derived units

- Force

$$[F] = [M] \cdot \frac{[L]}{[T]^2}$$

$$= \mathrm{Kg.m} / s^2 = \mathrm{N(newton)}$$

$$[S] = \frac{[F]}{[A]}$$

$$= \frac{N}{m^2} = \text{Pascal (Pa)}$$

$$1 \times 10^3 \text{ Pa} = 1 \text{ kPa}$$

$$1 \times 10^6 \text{ Pa} = 1 \text{ MPa}$$

1.15 Units And Preferred Units cont.

English Units

Base units

- Force (lb)
- Length L (in).
- Time T (s).

Derived units

Mass M

$$[M]=[F]\cdot\frac{[T]^2}{[L]}$$

$$=\text{lb}.s^2/in$$

$$[S]=\frac{[F]}{[A]}$$

$$=\frac{lb}{in^2}=\text{psi}$$

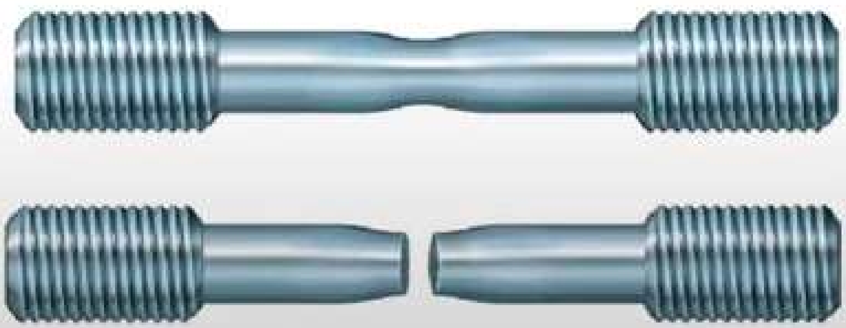
$$1\times10^3 \text{ psi}=1 \text{ kpi}$$

$$1\times10^6 \text{ psi}=1 \text{ Mpi}$$

Ductile vs. Brittle materials

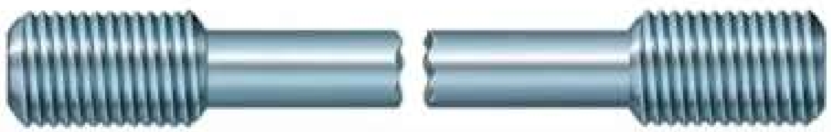
Ductile

- Failure occurs by slippage of the material along oblique surfaces and is due primarily to **shearing stresses** (form a cone shape of angle 45°).
- At fracture, the percentage of deformation is large (provide warning).



Brittle

- Failure occurs due to internal defects that initiate a crack perpendicular to the **normal stress**.
- At fracture, the percentage of deformation is small.



Tension failure of
a brittle material

2.1 Material Strength and Stiffness cont.

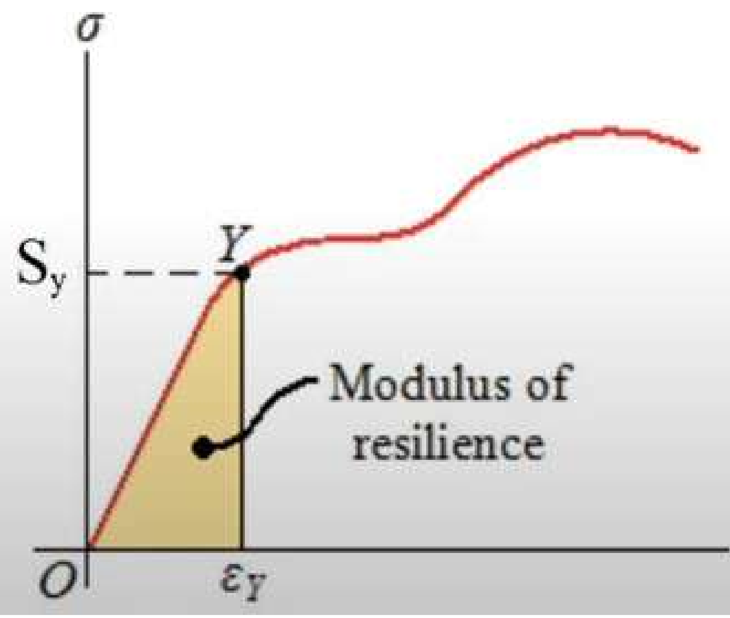
Hook's law is applicable until the proportional limit.

yield strength S_y is often defined by an offset method (*line is drawn at slope E with offset* ε = 0.002)

The modulus of resilience u_R of a material is the energy absorbed per unit volume without permanent deformation

$$u_R \approx \int_0^{\epsilon_y} \sigma \, d\epsilon$$

$$u_R \approx \frac{1}{2} S_y \epsilon_y = \frac{1}{2}(S_y)(S_y/E) = \frac{S_y^2}{2E}$$



2.1 Material Strength and Stiffness cont.

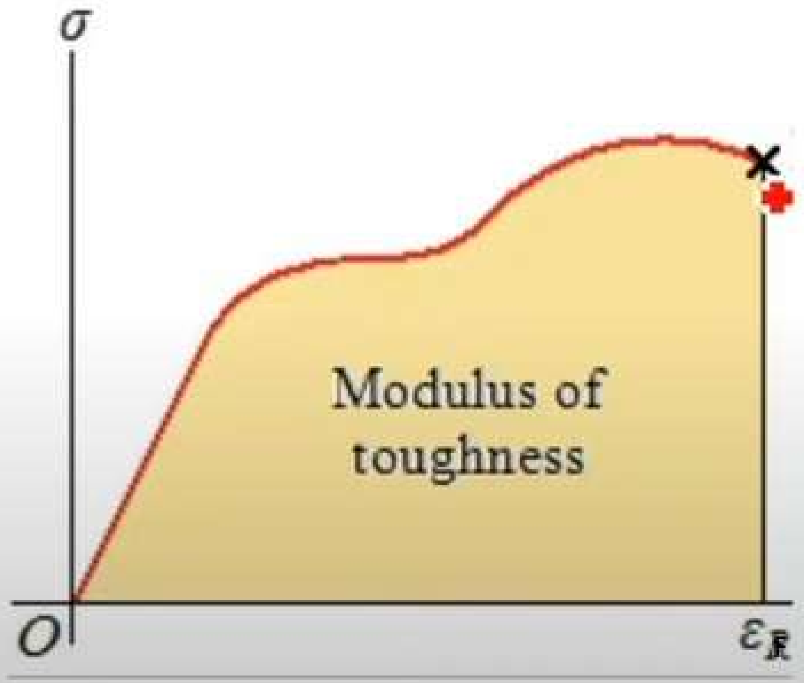
Specific strength is the strength of a material with respect to its density

$$\text{specific strength} = \frac{\text{strength}}{\text{density}}$$

The modulus of toughness u_T of a material is defined as the energy absorbed per unit volume without fracture

$$u_T = \int_0^{\epsilon_f} \sigma d\epsilon$$

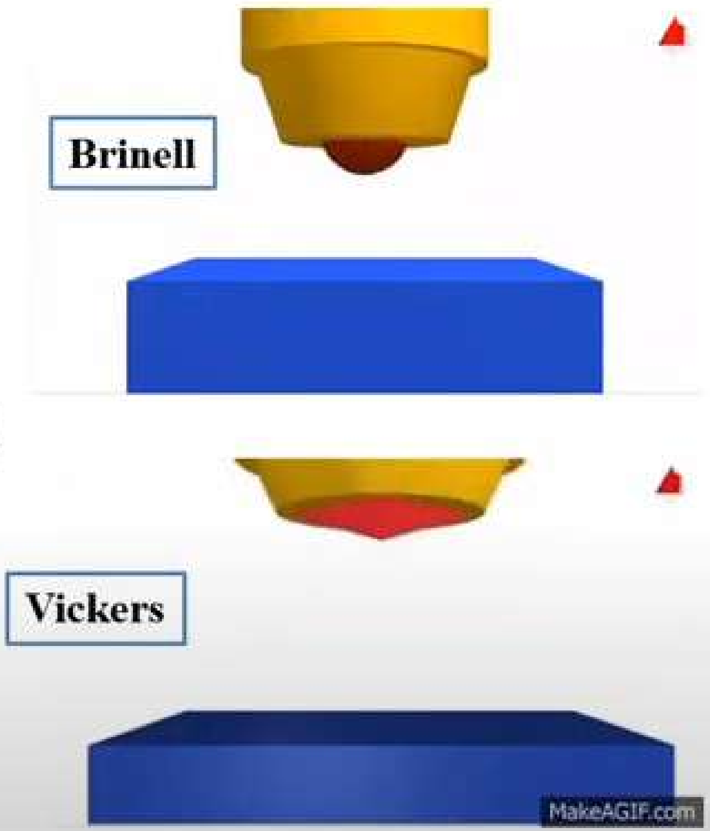
$$u_T \approx \left(\frac{S_y + S_{ut}}{2}\right)\epsilon_f$$



2.4 Hardness

Hardness: the resistance of a material to penetration by a pointed tool.

- Provide indication of resistance to scratching and wear.
- Strengths of some materials are closely related to hardness.
- Metals can be treated to increase their hardness



Hardness Tests

Brinell – 10 mm hardened steel ball and 500 or 3000 kg load. (H_B)

Rockwell – 1/16 in ball or a 120° cone shaped diamond indenter.

(R_A,R_B,R_C)

Vickers – diamond pyramid indenter.