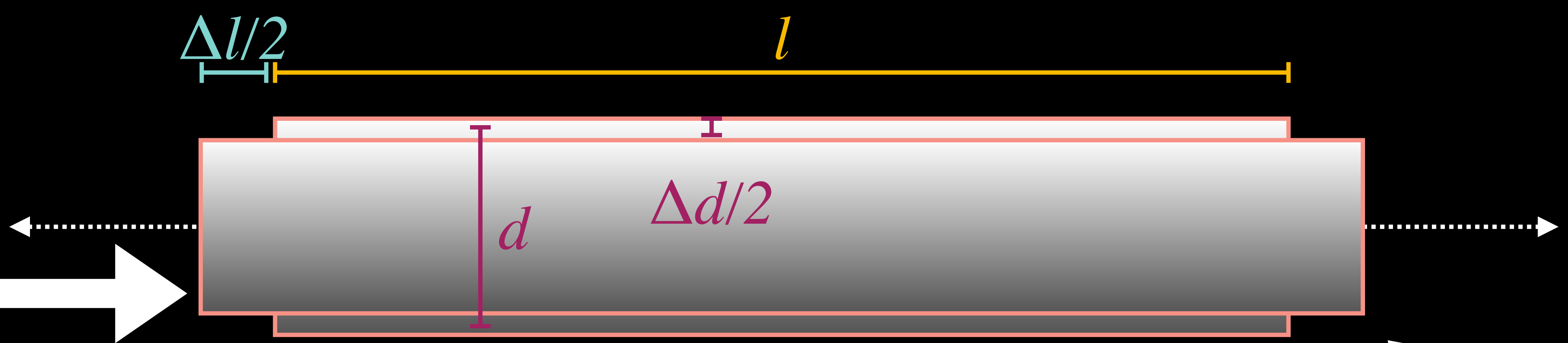
LAT/LONG DEFORMATION



Elongation in loaded (axial) dimension

Contraction in lateral dimension (cross section)

$$\epsilon_{long} = \frac{\Delta l}{l_0}$$

$$\epsilon_{lat} = -\frac{\Delta d}{d_0}$$

Negative value due to the contraction of the material.

- If the initial length *l* and change in length Δ*l* are known, and the initial diameter *d* and change in diameter Δ*d* are known…
  - …longitudinal strain ε_{long} and latitudinal strain ε_{lat} may be found.

NEXT WEEK (UPDATED)

- No lecture Monday (Public Holiday)
- Tuesday: meet here for Gearbox Assignment discussion
- Thursday: SolidWorks help session (I'll pop by Co239 and AM219 to help with SolidWorks; SolidWorks videos will be posted beforehand on Blackboard)

POISSON'S RATIO

- Poisson observed isotropic & homogeneous materials
  - He noted that the ratio between ε_{long} and ε_{lat} is a constant.
  - This constant is known as Poisson's Ratio, v (nu)
- A lower value of v means that there is less contraction when the specimen is placed under tension and less expansion when the specimen is compressed.
  - Most materials have Possion's Ratios between 0 and 0.5.
- Cork's low v ($v \approx 0.0$) means that wine bottle corks fit easily without expansion.
- v becomes important when considering fits of materials under tension and compression.
  - e.g., pipes under pressure
  - or precision fits of loaded parts
- (Auxetic: material with negative Poisson's ratio (!!))

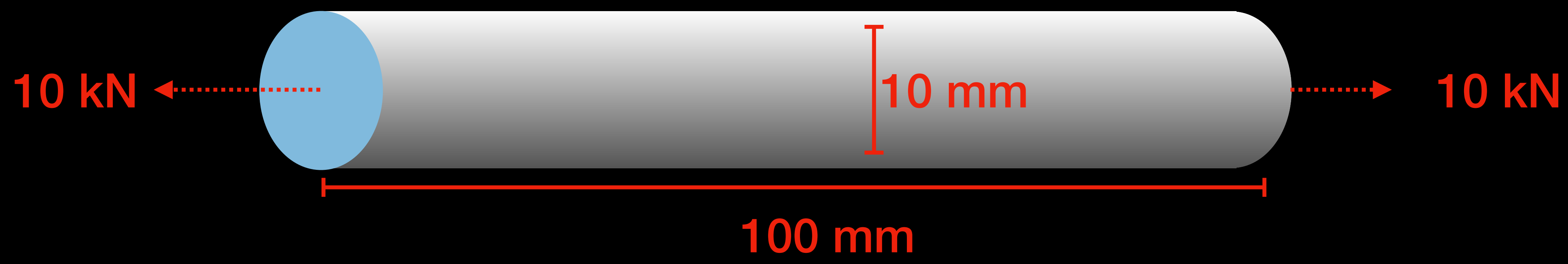
$$\nu = -\frac{\epsilon_{lat}}{\epsilon_{long}}$$

MATERIAL	POISSON'S RATIO (ν)
Lead	0.425
Phosphor Bronze	0.349
Carbon steel	0.292
Glass	0.245

POISSON'S RATIO

- A carbon steel rod (circular cross section; *E* of 200 GPa, *v* = 0.292) has a diameter of 10 mm and an initial length of 100 mm. Find the diameter of the rod when an axial load of 10 kN is applied.

1) Make a drawing.



POISSON'S RATIO

- A carbon steel rod (circular cross section; *E* of 200 GPa, *v* = 0.292) has a diameter of 10 mm and an initial length of 100 mm. Find the diameter of the rod when an axial load of 10 kN is applied.

2) Calculate normal stress & strain in the rod.

kN/mm² = GPa

$$\sigma = \frac{P}{A_0} \quad \text{where} \quad A_0 = \frac{1}{4}\pi d_0^2 \quad = \frac{10\ kN}{\frac{\pi}{4}(10\ mm)^2} = 0.1273\ \frac{kN}{mm^2}$$

Hooke's Law: relates stress to strain

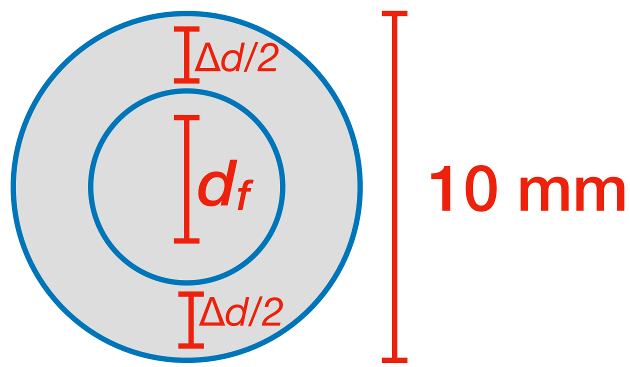
$$\sigma = E\epsilon \qquad \epsilon_{long} = \frac{\sigma}{E} = \frac{0.1273\ GPa}{200\ GPa} = 0.0006365$$

POISSON'S RATIO

- A carbon steel rod (circular cross section; *E* of 200 GPa, *v* = 0.292) has a diameter of 10 mm and an initial length of 100 mm. Find the diameter of the rod when an axial load of 10 kN is applied.

3) Calculate ε_{lat} using Poisson's Ratio

$$\nu = -\frac{\epsilon_{lat}}{\epsilon_{long}}$$



$$\epsilon_{lat} = (-0.292)(0.0006365)$$
$$\epsilon_{lat} = -0.0001859$$

Negative value: it constricted.

POISSON'S RATIO

- A carbon steel rod (circular cross section; *E* of 200 GPa, *v* = 0.292) has a diameter of 10 mm and an initial length of 100 mm. Find the diameter of the rod when an axial load of 10 kN is applied.

4) Calculate the change in diameter

$$\epsilon = \frac{\delta}{l_0} \quad \epsilon_{lat} = \frac{\Delta d}{d_0} \quad \Delta d = (-0.0001859)(10\ mm)$$

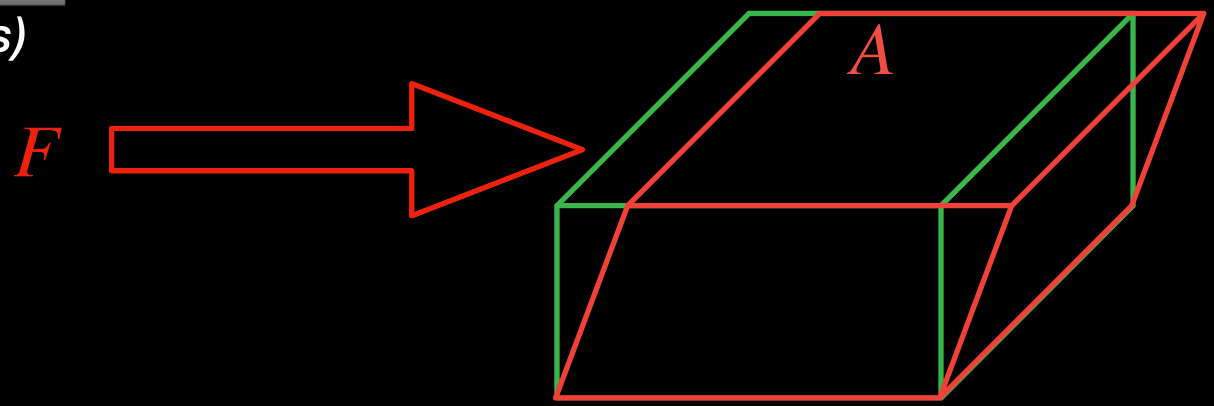
$$\Delta d = -0.001859\ mm$$

5) Calculate the final diameter

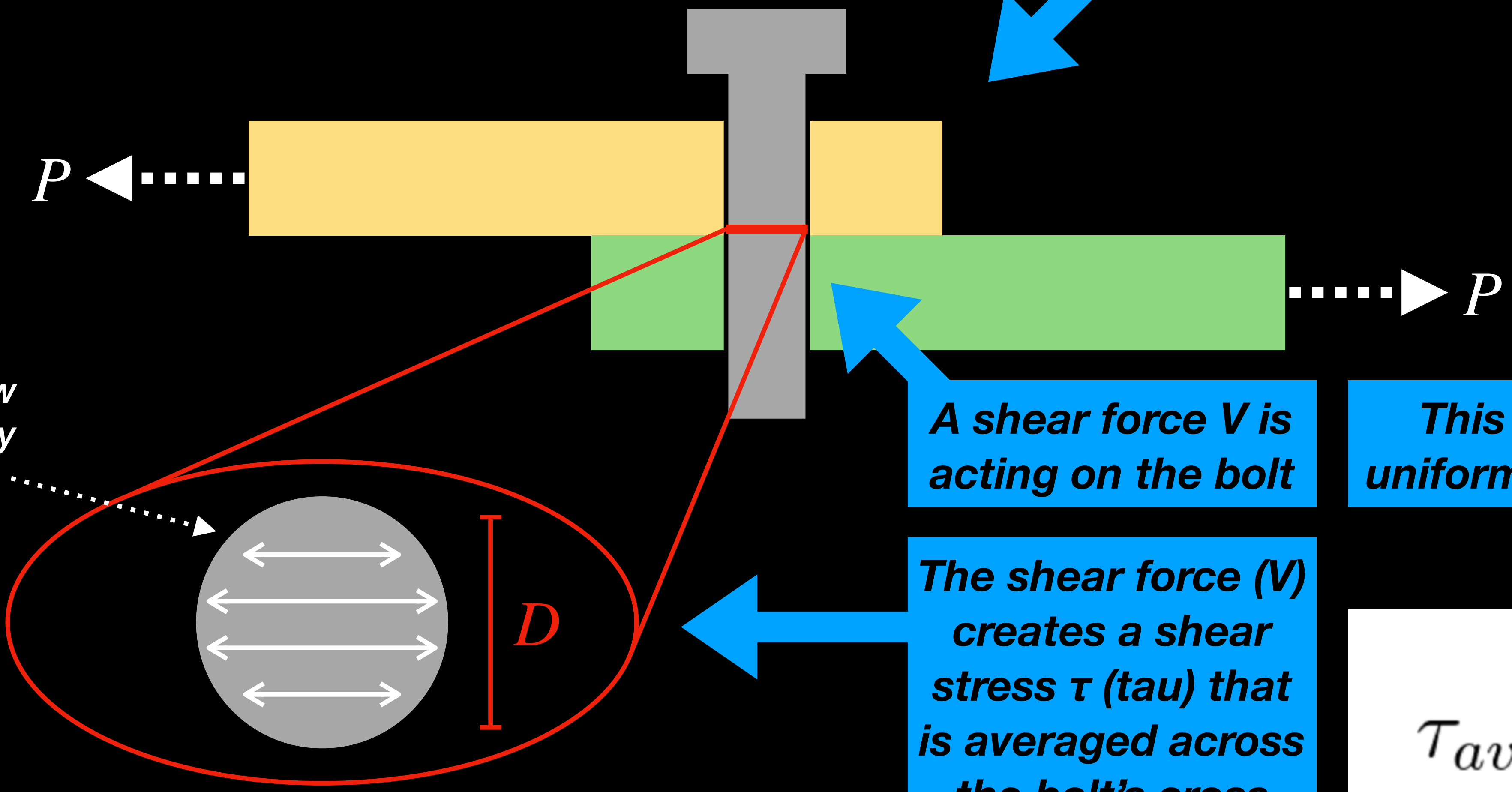
$$\Delta d = d_f - d_0 \quad d_f = \Delta d + d_0 \quad \boxed{d_f = 9.9981\ mm}$$

SHEAR STRESS

(Tensile stress)



A single shear connection: Two plates with force transferred at one plane. The whole load is transferred through the single bolted connection (P/1)



Note how these stress lines are moving perpendicular to how they would were they normal stresses

A shear force V is acting on the bolt

This assumes a uniform shear stress

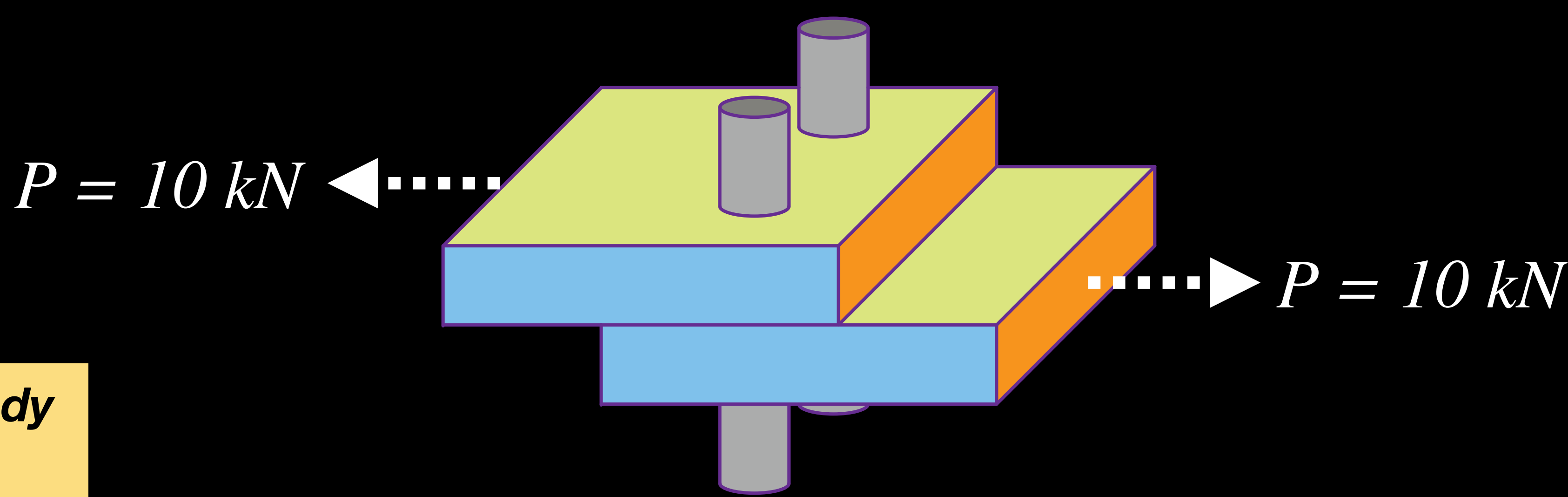
The shear force (V) creates a shear stress τ (tau) that is averaged across the bolt's cross sectional area A

$$\tau_{avg} = \frac{V}{A}$$

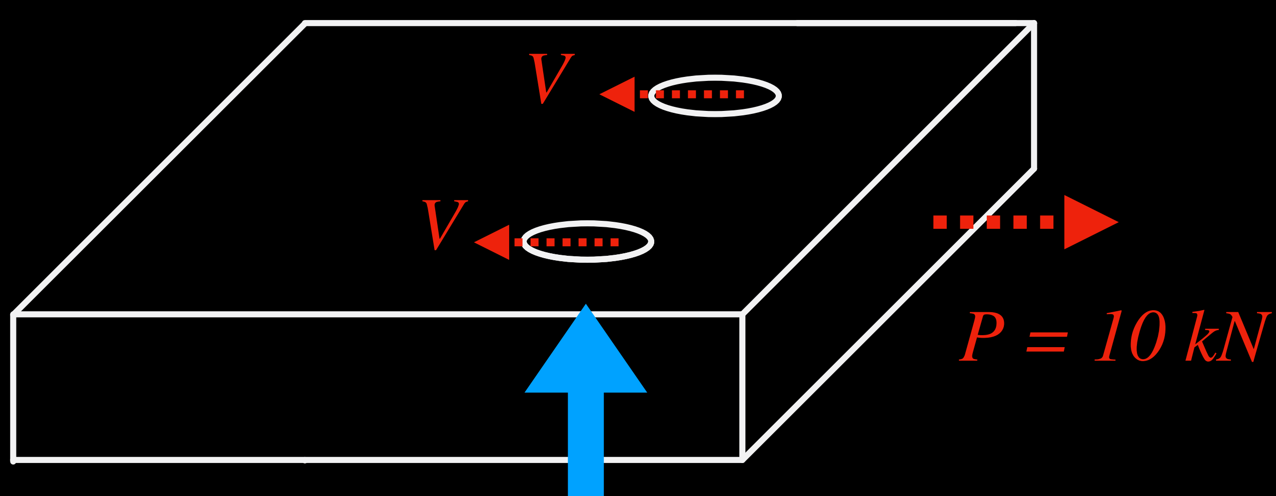
Note: With correct preload, the bolt/rivet brings the materials into contact such that their friction provides much of the strength

EXAMPLE: SHEAR STRESS

- Two pieces of 3 mm thick Perspex are joined with two 3 mm rods. What is the average shear stress in the rods when 10 kN of load (in tension to the two pieces of Perspex) is applied?



1) Draw a free body diagram of the bottom (or top) plate.



Normal load P results in two areas of shear load V

$$V = \frac{P}{2} = 5\ kN$$

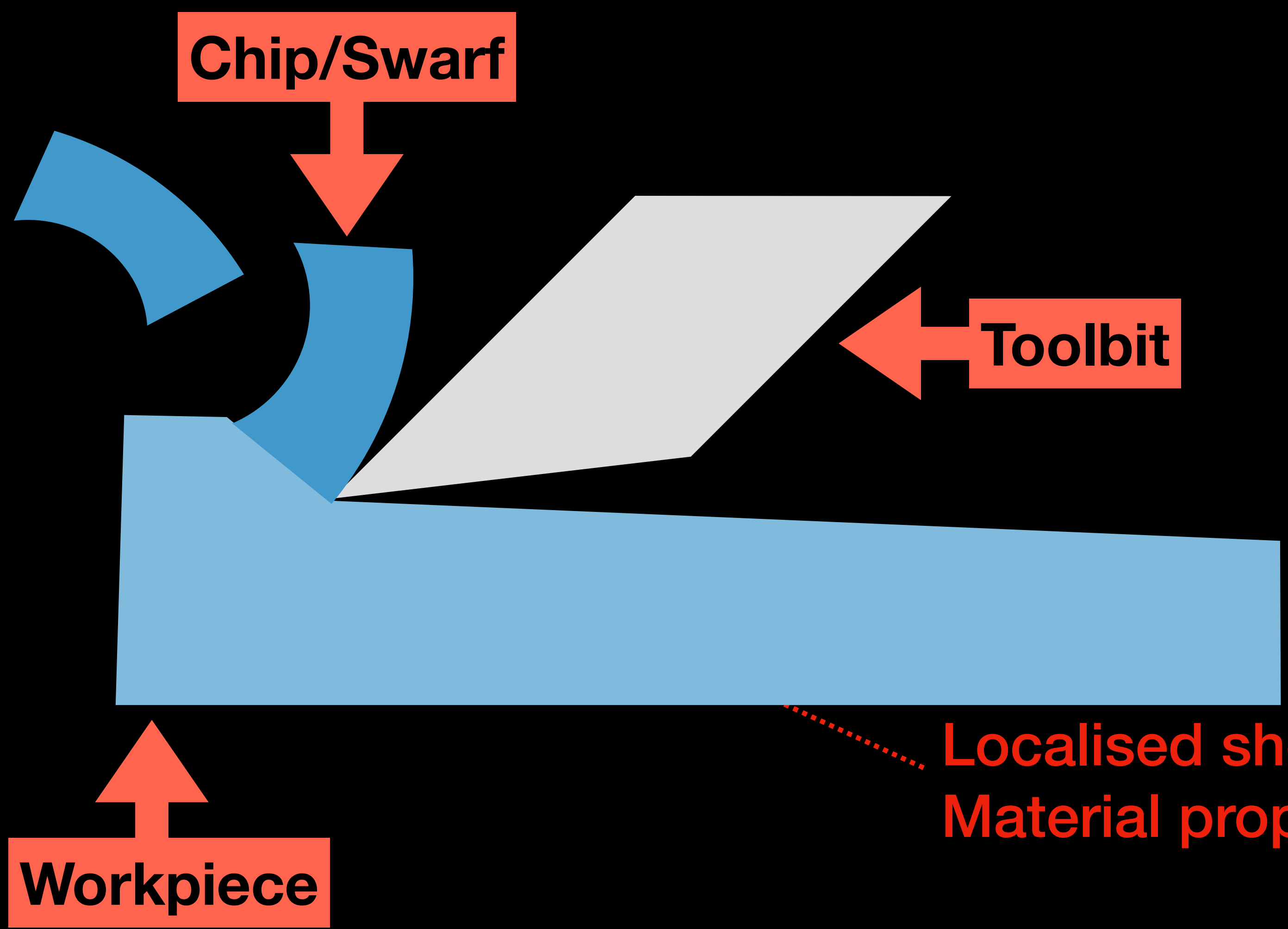
2) Find the average shear stress.

$$\tau_{avg} = \frac{V}{A}$$

$$A = \frac{\pi}{4}(3\ mm)^2 = 7.065\ mm^2$$

$$\tau_{avg} = \frac{5\ kN}{7.065\ mm^2} = 0.7071\ GPa$$

CONVENTIONAL MACHINING



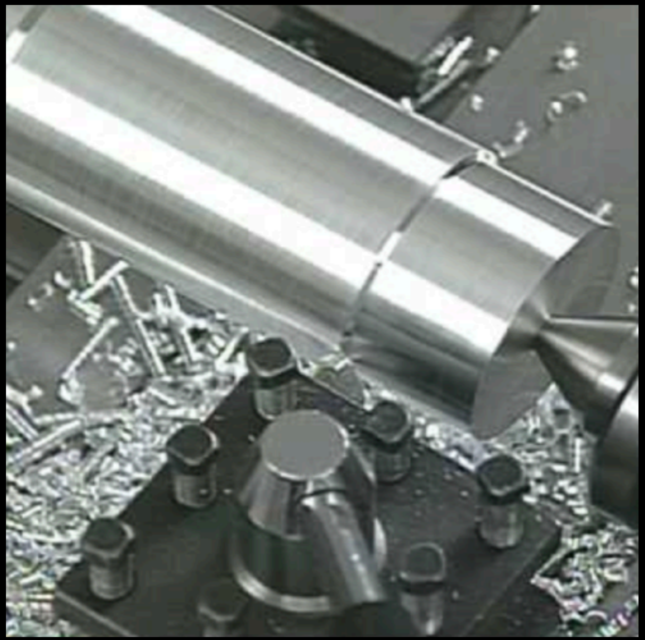
Machining: A process in which unwanted material is removed from a workpiece in the form of chips.

Localised shear stresses fracture the workpiece.
Material properties & cutter shape dictate chip shape.

MACHINING PROCESSES

https://www.youtube.com/watch?v=HflalSnqHOk

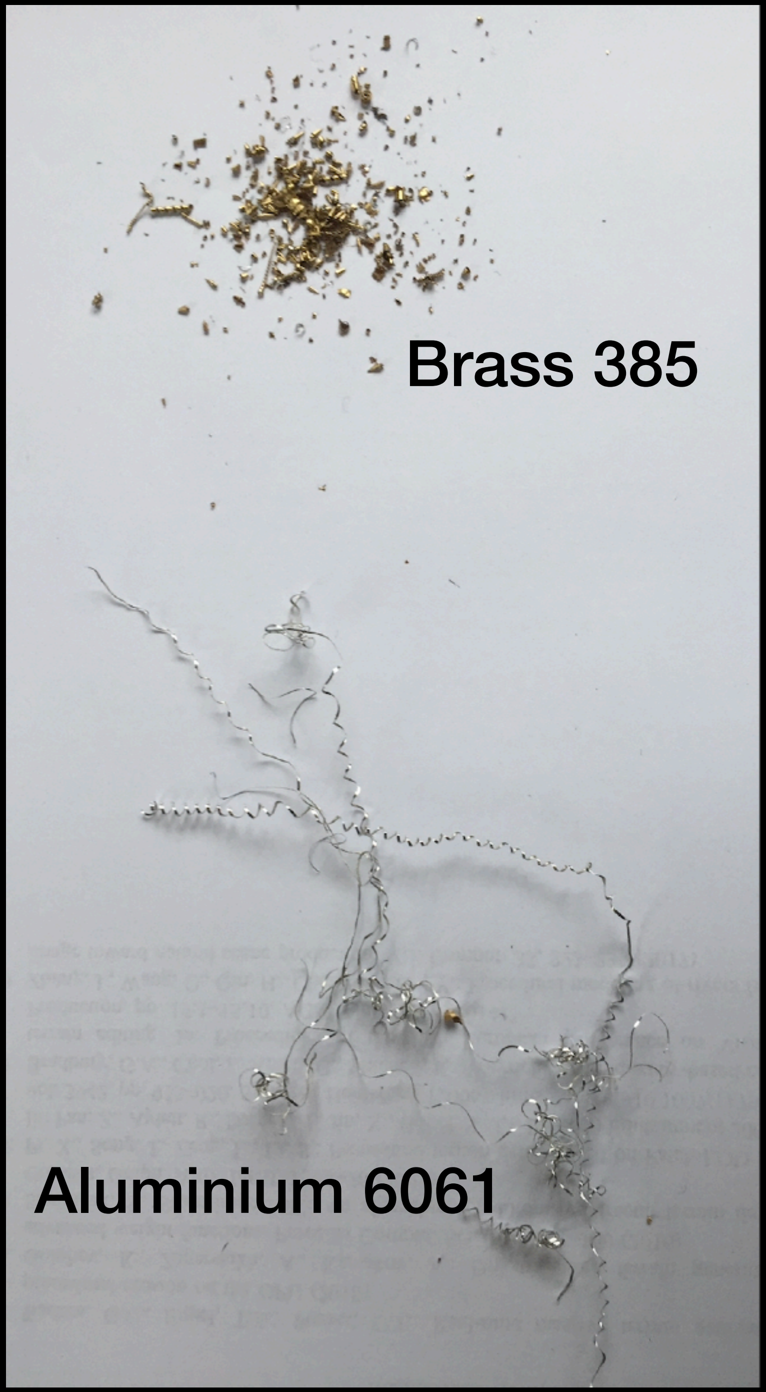
MACHINING TYPE	TOOL BEHAVIOUR	WORKPIECE BEHAVIOUR
Milling	Tool rotates	Workpiece moves along a straight line
Turning	Tool moves along a straight line	Workpiece rotates
Drilling	Tool rotates and moves along a straight line	Workpiece is stationary
Shaping	Tool moves along a straight line; cutting edge is perpendicular to cut surface	Workpiece is stationary (sometimes moves instead of tool)
Broaching	Tool moves along a straight line; cutting edge is parallel to cut surface	Workpiece is stationary (sometimes moves instead of tool)



https://www.youtube.com/watch?v=J63dZsw7Ia4

MACHINABILITY

- When it comes to manufacturing a component using machining processes, it's very important to consider how the material responds to this machining.
  - A material with good machinability (free machining): material can be removed at low power, with low tooling wear, good chip behaviour, and a good surface finish.
- Machinability is a hybrid of a few more fundamental material properties: hardness, ductility, strength/toughness, etc.
- Different alloys can have very different machinabilities.
- Practically, machinability is often among the most critical criteria in material choice.



FREE MACHINING BRASS

Easy-to-Machine Architectural 385 Brass Rods

- Yield Strength:
  Inch sizes: 16,000 psi
  Metric sizes: 60,000 psi
- Hardness:
  Inch sizes: Rockwell B40 (Soft)
  Metric sizes: Rockwell B55 (Soft)
- Temper:
  Inch sizes: H02 (1/2 Hard)
  Metric sizes: 1/2 Hard
- Heat Treatable: No
- Specifications Met:
  Inch sizes: ASTM B455
  Metric Sizes: European Standard EN 12164

Often called architectural bronze, 385 brass is easy to machine and has excellent formability when heated. It is typically used for handrails, ornamental trim, and hardware, such as hinges and lock bodies.

BRASS 385 (https://www.mcmaster.com/brass-alloy-385/)

FREE MACHINING AL

Easy-to-Machine 2011 Aluminum Rods

- Yield Strength: 38,000 psi
- Hardness: Brinell 115 (Soft)
- Temper: T3
- Fabrication: Cold Drawn
- Specifications Met: ASTM B211

2011 has the best machinability of all the aluminum alloys. It is the most selected aluminum for screws, tube fittings, hose parts, and other items that require extensive machining.

MACHINING STAINLESS STEEL

- Many advantages of stainless steel:
  - Corrosion-resistant
  - Relatively strong (esp. amongst corrosion-resistant materials!)
  - Many alloys are relatively inexpensive
- Can be difficult to machine:
  - Prone to work-hardening during machining
  - Best machined with modern tungsten carbide tooling

MACHINING THERMOPLASTICS

- Thermoplastics have a very wide range of responses to machining
- Considerations: thermal expansion when heated by machining processes
- Chip/swarf can be difficult to control
- Cutting tool must be very sharp - dull tools melt materials
- PMMA (Perspex): brittle
- UHMWPE: soft, poor chip-breaking, cheap
- Acetal/Delrin/Polyoxymethylene: good machinability - excellent finish, more expensive, one of the best thermoplastics for machining.

CHOOSING MATERIALS

- When choosing metals, a number of properties must be considered:
  - Strength, hardness, ductility…
  - But also:
  - Strength-to-weight ratio (strength/mass)
  - Corrosion resistance
  - Electrical conductivity
  - Machinability
  - Behaviour at high temperatures
  - Cost
- We've looked at many material properties now…
  - … we'll take a quick break next week to look at some CAD/CAM approaches…
  - …and will spend the first lecture in Week 9 looking at selecting materials based upon these properties.

MACHINING VIDEOS!

- Oxtoolco (toolmaking and metrology): https://www.youtube.com/channel/UCZC9LGZLfyjrKT4OZne-JNw
- Applied Science (Instrumentation and exotic materials machining): https://www.youtube.com/channel/UCivA7_KLKWo43tFcCkFvydw
- ROBRENZ (toolmaking): https://www.youtube.com/channel/UCn4U3aEr6L2nLe1m_3as6JQ
- Dan Gelbart (general fabrication): https://www.youtube.com/channel/UCYA1VjSKXgNVh03wjw_HSRA
- This Old Tony (fun, general machining & CNC): https://www.youtube.com/channel/UC5NO8MgTQKHAWXp6z8XI7yQ
- Clickspring (general machining, lots of non-ferrous work): https://www.youtube.com/channel/UCworsKCR-Sx6R6-BnIjS2MA