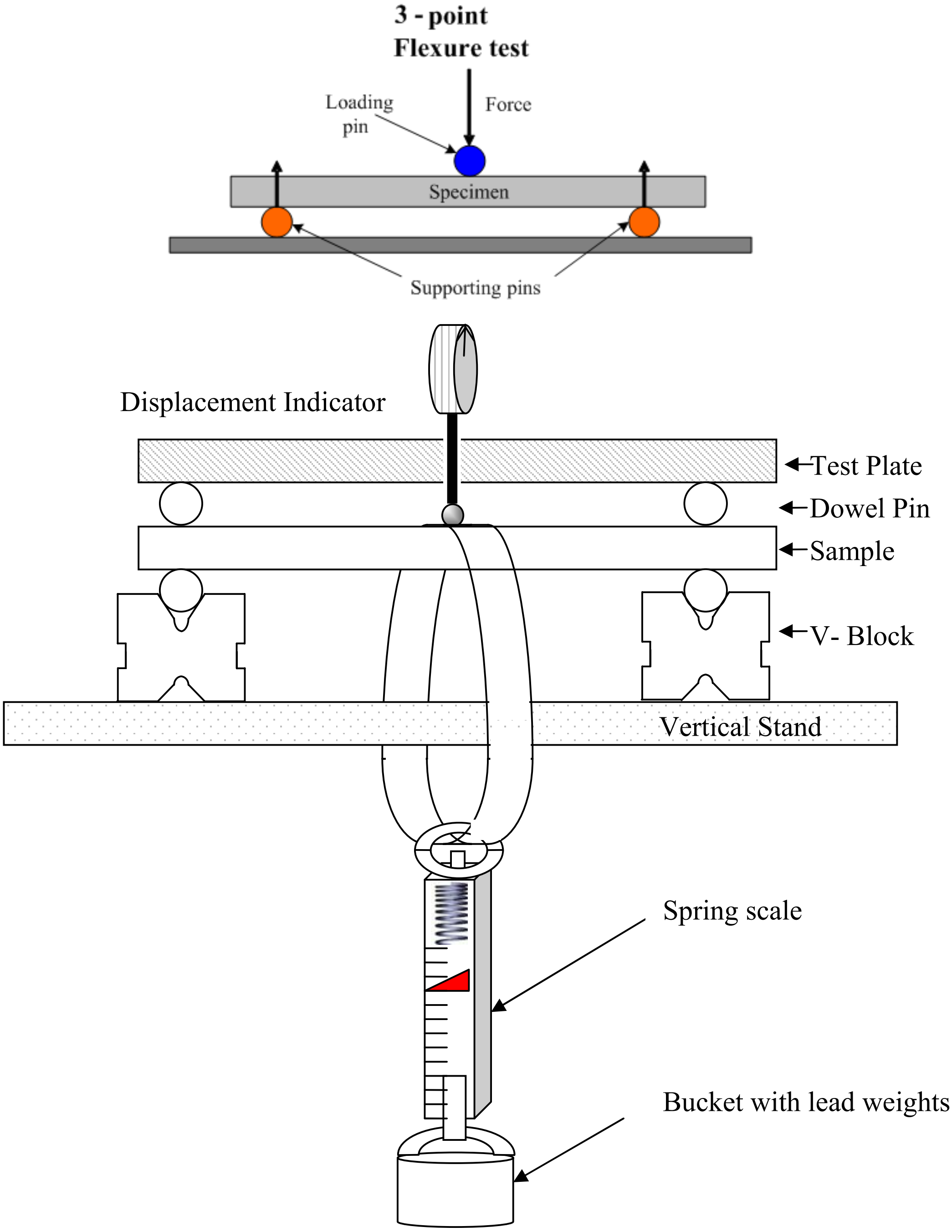
Lab 8: Properties of Materials

Background: In this lab you will repeat a few simple measurements on many different kinds of materials to appreciate their different properties which include elasticity, thermal conductivity and diffusivity, density, opacity, and their coefficient of thermal expansion.

Beam Deflection Setup (not to scale)

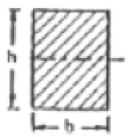
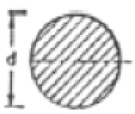


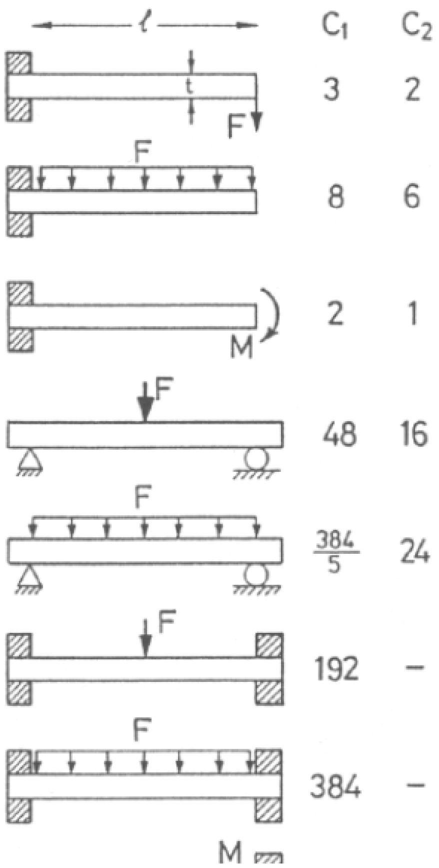
Common Deflection Definitions

Quantity	**Definition**	**Symbol**	**Units**	**English Units**
Stress	tension/area = *F / A*	σ (sigma)	N m^{-2} = Pa	psi
Strain	extension per original length = Δ*x / x*	ε (epsilon)	no units (ratio of two lengths)	no units
Young's Modulus = Modulus of Elasticity	stress/strain	E	N m^{-2} = Pa	psi
Vertical Load	deflection force	F	N	lbs
Deflection	elastic deformation	δ	m	in
Length	sample length	l	m	in
Second Moment	See table below	I	m^4	in^4

To measure Young's modulus by deflecting the sample under a measured load

- Repeat this exercise for each of the following:
  - Aluminum (pick an alloy)
  - 2 Plastic samples
  - Stainless steel
- Measure the sample's dimensions (thickness (h) and height (b)) with calipers
- Set up the sample as shown in the figure on page 1
- Lift the vertical table using the black pedal until a noticeable deflection can be measured by the displacement indicator. Write down both the deflection and the measured load as read from the spring scale.
- Use the following formula to calculate the Modulus of Elasticity for the material.

SECTION	Cross-sectional area A(m^2)	Second moment about neutral axis I (m^4)	Equivalent polar moment K (m^4)	I/y_m (m^3)	H (m^3)
	bh	$\frac{bh^3}{12}$	$\frac{1}{3}hb^3\left(1-0.58\frac{b}{h}\right)$ (b<h)	$\frac{bh^2}{6}$	$\frac{bh^2}{4}$
	$\frac{\pi d^2}{4}$	$\frac{\pi}{64}d^4$	$\frac{\pi}{32}d^4$	$\frac{\pi}{32}d^3$	$\frac{1}{6}d^3$



$$\delta = \frac{F\ell^3}{C_1 E I} = \frac{M\ell^2}{C_1 E I}$$

$$\theta = \frac{F\ell^2}{C_2 E I} = \frac{M\ell}{C_2 E I}$$

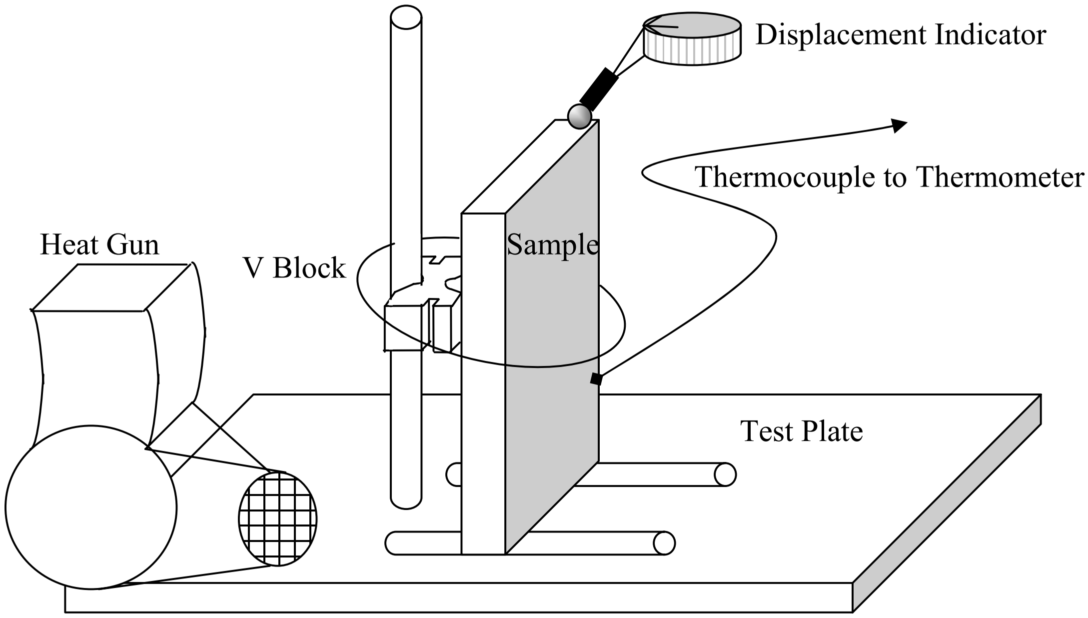
E = YOUNGS MODULUS (N/m^2)
δ = DEFLECTION (m)
F = FORCE (N)
M = MOMENT (Nm)
ℓ = LENGTH (m)
b = WIDTH (m)
t = DEPTH (m)
θ = END SLOPE (–)
I = SEE TABLE 2 (m^4)
y = DISTANCE FROM N.A.(m)

Density

Measure the physical dimensions of the samples so you can calculate the volume. Then measure the mass on the electronic scale. Do not overload the scale. Its upper limit is 2.2 kg.

You may want to do some experiments just with the scale. For example, what is the mass of a drop of water? Zero the scale with an aluminum foil sample pan and then add a drop of water, or other liquid. What does a nut or screw weigh?

Thermal Properties Setup



(To relatively measure the thermal conductivity, diffusivity, and coefficient of thermal expansion of each sample)

- Do this experiment for one sample of aluminum, titanium, and stainless steel
- Measure the sample's original dimensions
- Hold the sample in your hand
  - Does it feel warm/cold after 10 seconds?
  - Based on this, rate the samples from least to highest thermal conductivity
- Place the sample in the setup as shown
- You will need three people to take three different measurements: 1 keeps track of time, 1 writes down the temperature reading from the thermometer, and 1 records the measurements from the displacement interferometer
- Heat up one end of the sample to for 20 seconds. Every 5 seconds, write down the required measurement.
- As the sample cools, take measurements every 20 seconds for 1 minute.
- What relationship does your data indicate?
- If available, use the IR thermal sensor to measure the temperature per length of the sample, make similar measurements

Common Thermal Definitions

Quantity	Definition	Symbol	Units	English Units
Thermal conductivity	see eq. below	k	W/(m K)	Btu·ft/(h·ft²·°F)
Area	surface area = b * h	A	m^2	ft^2
Temperature difference btwn ends of sample	T_1-T_2	ΔT	K	psi
Time difference	t_{end}-t_{start}	Δt	s	s

Added heat	from heat gun	ΔQ	J	BTU ft
Thermal diffusivity	see eq. below	K	m	in
Volume	A*l	V	m^3	ft^3

In terms of the added heat (Q), what is the thermal conductivity and diffusivity?

$$\text{Thermal conductivity: } k = \frac{\Delta Q}{A \times \Delta t} \times \frac{x}{\Delta T}$$

$$\text{Thermal diffusivity: } \kappa = \frac{k \times \Delta T}{V \times \Delta Q}$$

$$\text{Coefficient of thermal expansion: } \frac{\frac{new\_length}{original\_length}}{\frac{end\_temperature}{start\_temperature}}$$

Do your relative measurements match your predictions from above?

Spring Wires

Goal: Become familiar with elastic materials often used in flexures and other optical mounts

- Cut off a measured amount of wire and bend into a right angle, then try to bend it back to its original shape
- Use the shape-memory wire to make your name, heat it up with the heat gun, stretch it out, then lay it on the table

Optical Windows

Goal: Have student become familiar with different optical materials, weight, opacity, etc

- Calcium Fluoride
- Silicon
- Germanium
- Sapphire
- Zinc Selenide
- Zinc Sulfide