EMERGENCY EVACUATION PROCEDURES

Important: The Michigan Bureau of Fire Services has adopted new rules for colleges and universities effective 2015.

1. Only residence halls are required to hold fire and tornado drills.
2. In lieu of fire drills in other university buildings all faculty and instructional staff are required to do the following on the first day of class:
   - Explain the university fire evacuation procedures to the class (see below).
   - Explain the locations of the primary and secondary exit routes for your class location.
   - Explain your designated safe location where the class will meet after evacuating the building.
3. The class instructor is responsible for directing the class during a building evacuation.

General evacuation procedure:
- Use the nearest safe exit route to exit the building. The nearest safe exit from room 19-104A is the front (south) entrance that is close to the MUB circle. The secondary exit is in the middle of the building, either the west or east entrance (both are equally close).
- Close all doors on the way out to prevent the spread of smoke and fire.
- After exiting, immediately proceed to a safe location at least 100 feet from the building. Our designated safe location is at the mailbox near the entrance to parking lot 12 (near the MUB small parking lot).
- Do not re-enter the building until the all-clear is given by Public Safety or the fire department.
Let’s begin with an Introductory Overview of the Topic

Polymer Rheology

Rheo-  
rei – Greek for flow

What is rheology anyway?

Rheology = the study of deformation and flow.

We are interested in fluids
How they deform;
transmit, produce, react to imposed stresses

Why?

Why?
• Advance technology
• Innovate
• Manage existing processes

Non-intuitive, unexpected outcomes—need a model to know what’s going on!
(avoid surprises, undesirable fluid behavior; exploit phenomena)

For many of these situations, the fluid/deformation behavior is not Newtonian

not Newtonian?
For many important applications, the fluid/deformation behavior is **not Newtonian**

**Newtonian**
Continuum modeling with the **Newtonian** constitutive equation

\[ \tau = \mu (\nabla \varepsilon + (\nabla \varepsilon)^T) \]

Can predict \( \tau, \varepsilon \) (continuum predictions)

**Non-Newtonian**
Continuum modeling with the **some other** constitutive equation

\[ \tau = f(\varepsilon) \]


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**CM4650 Polymer Rheology: Introduction**

**Fluid Mechanics is a Big Subject**
- Mechanical Energy Balance
- Newtonian constitutive equation
- Navier-Stokes equations
- Laminar-Turbulent flow
- Potential flow
- Boundary layers—drag, lift
- Perturbation analysis
- Computational Fluid Dynamics (CFD)

**Rheology is also a Big Subject**
- Cauchy momentum equation
- Stress constitutive equation
- Stable/unstable flows

**A great deal of effort has gone into addressing the challenges in the Navier-Stokes equations**

**Society of Rheology founded 1929**

**Stumbling block:** What is the stress-deformation relationship if the fluid is non-Newtonian?

Much of the field of rheology is devoted to addressing challenges linked to modeling material-deformation/stress relationships.
To get started, let’s take a look at what Newtonian versus Non-Newtonian looks like in actual fluids.
# Introduction to Non-Newtonian Behavior

**Rheological Behavior of Fluids, National Committee on Fluid Mechanics Films, 1964**

<table>
<thead>
<tr>
<th>Type of fluid</th>
<th>Momentum balance</th>
<th>Stress – Deformation relationship (constitutive equation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inviscid (zero viscosity, $\mu=0$)</td>
<td>Euler equation (Navier-Stokes with zero viscosity)</td>
<td>Stress is isotropic</td>
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<tr>
<td>Newtonian (finite, constant viscosity, $\mu$)</td>
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<td>Stress is a function of the instantaneous velocity gradient</td>
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**Velocity gradient tensor, $\dot{\gamma}$**

\[
\tau(t) = \mu \dot{\gamma}(t)
\]

\[
\tau(t) = f(\dot{\gamma})
\]

---

**CM4650 Polymer Rheology: Introduction**

**Rheological Behavior of Fluids – Newtonian**

1. **Strain response to imposed shear stress**
   - shear rate is constant

\[
\dot{\gamma} = \frac{d\gamma}{dt} = \text{constant}
\]

2. **Pressure-driven flow in a tube (Poiseuille flow)**
   - viscosity is constant

\[
Q = \frac{\pi R^4 \Delta P}{8 \mu L}
\]

3. **Stress tensor in shear flow**
   - only two components are nonzero

\[
\tau = \begin{bmatrix}
0 & \tau_{12} & 0 \\
\tau_{21} & 0 & 0 \\
0 & 0 & 0
\end{bmatrix}_{123}
\]
1. Strain response to imposed shear stress
   • shear rate is variable

2. Pressure-driven flow in a tube (Poiseuille flow)
   • viscosity is variable

3. Stress tensor in shear flow
   • all 9 components are nonzero

\[ \tau = \begin{pmatrix}
\tau_{11} & \tau_{12} & \tau_{13} \\
\tau_{21} & \tau_{22} & \tau_{23} \\
\tau_{31} & \tau_{32} & \tau_{33}
\end{pmatrix} \]

\[ Q = f(\Delta P) \]

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Examples from the film of . . .

Dependence on the history of the deformation gradient

- Polymer fluid pours, but springs back
- Elastic ball bounces, but flows if given enough time
- Steel ball dropped in polymer solution “bounces”
- Polymer solution in concentric cylinders – has fading memory
- Quantitative measurements in concentric cylinders show memory and need a finite time to come to steady state

Non-linearity of the function \( \tau = f(\dot{\gamma}) \)

- Polymer solution draining from a tube is first slower, then faster than a Newtonian fluid
- Double the static head on a draining tube, and the flow rate does not necessarily double (as it does for Newtonian fluids); sometimes more than doubles, sometimes less
- Normal stresses in shear flow
- Die swell

NCFM Film on Rheological Behavior of Fluids

- Search for NCFMF
- web.mit.edu/hml/ncfmf.html
- Also on YouTube

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**Introduction to Non-Newtonian Behavior**

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**Velocity gradient tensor, \(\dot{\gamma}\)**

\[ \tau(t) = \mu \dot{\gamma}(t) \]

\[ \tau(t) = f(\dot{\gamma}) \]

Carefully designed experiments to distinguish material behavior

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CM4650 Polymer Rheology: Introduction

Course Outline
Part I:
- Vectors and tensors
- Newtonian fluids
  Exam 1
Part II:
- Standard Flows
- Material Functions
- Experimental Observations
Part III: Constitutive Equations
- Generalized Newtonian
  Exam 2
- Linear Viscoelastic
- Nonlinear Viscoelastic
Part IV:
- Rheometry
  Final Exam

“Carefully designed experiments to distinguish material behavior”

Stress-deformation models
Measurement techniques