

058:160  
Intermediate Mechanics of Fluids

**Class Notes**  
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Prepared by:  
Professor Fred Stern

Typed by:  
Derek Schnabel (Fall 2004)  
Nobuaki Sakamoto (Fall 2006)  
Hamid Sadat-Hosseini (Fall 2006)  
Maysam Mousaviraad (Fall 2006)

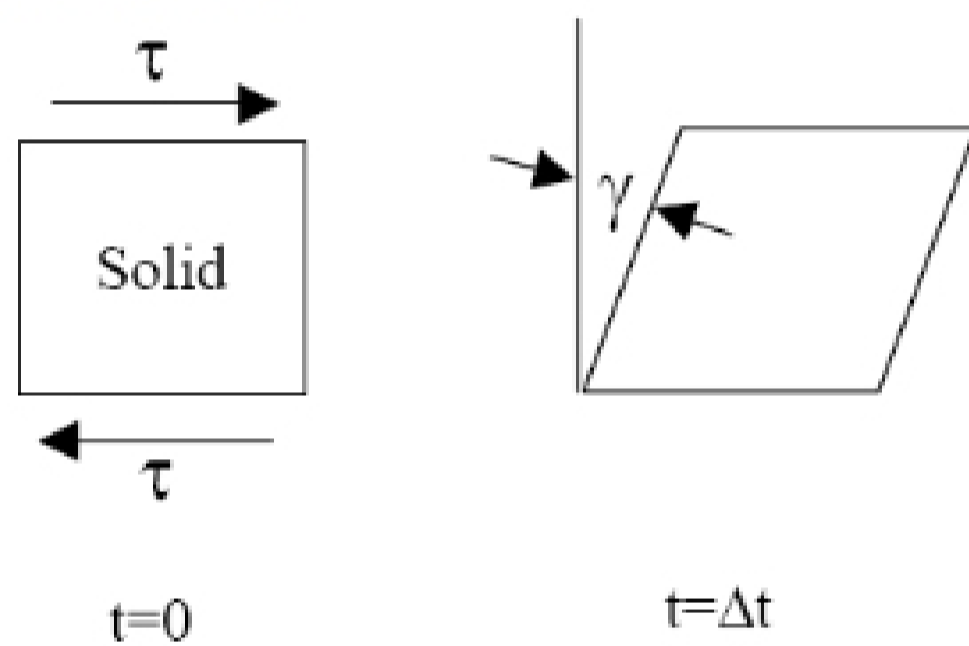
Corrected by:  
Jun Shao (Fall 2004)  
Mani Kandasamy (Fall 2005)  
Tao Xing, Hyun Se Yoon (Fall 2006)  
Hamid Sadat-Hosseini (Fall 2007-2010)

# Chapter 1: Introduction

## Definition of a fluid:

A fluid cannot resist an applied shear stress and remain at rest, whereas a non-fluid (i.e., solid) can.

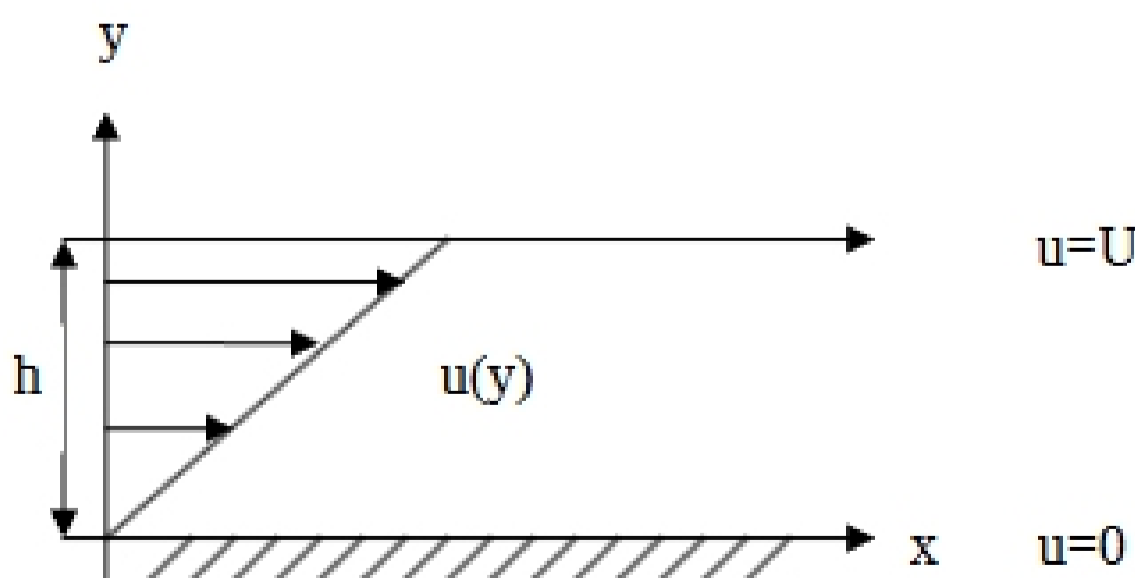
Solids resist shear by static deformation up to an elastic limit of the material, after which they undergo fracture.



Elastic solid:  $\tau \propto \gamma = \text{strain}$   
 $\tau = G \gamma$

$G = \text{shear modulus}$

Fluids deform continuously (undergo motion) when subjected to shear stress. Consider a fluid between two parallel plates, with the lower one fixed and the upper moving at speed  $U$ , which is an example of Couette flow (i.e, wall/shear driven flows)



$$\underline{V} = u(y) \hat{i}$$

1-D flow velocity profile

### No slip condition:

Length scale of molecular mean free path ( $\lambda$ )  $\ll$  length scale of fluid motion ( $\ell$ ); therefore, macroscopically there is no relative motion or temperature between the solid and fluid in contact.

$$\text{Knudsen number} = K_n = \lambda/\ell \ll 1$$

Exceptions are rarefied gases and gas/liquid contact line.

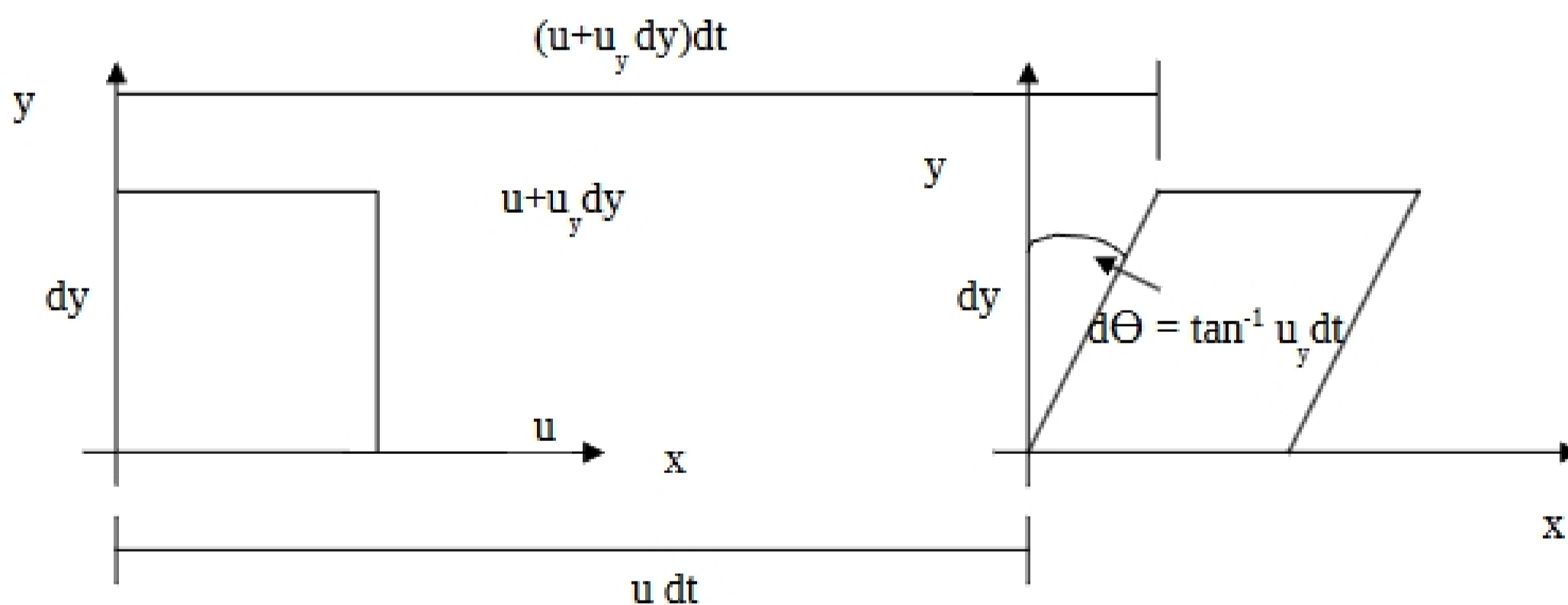
### Newtonian fluids:

$$\tau \propto \dot{\theta} = \text{rate of strain}$$

$$\tau = \mu \dot{\theta}$$

$\mu$  = coefficient of viscosity

### Rate of Strain:



Fluid element with sides parallel to the coordinate axes at time  $t=0$ .

Fluid element deformation at time  $t + dt$

$$\tan d\theta = \frac{u_y dy dt}{dy}$$

$$\frac{d\theta}{dt} = \dot{\theta} = u_y$$