How organism structures and functions are shaped by their surrounding media

Through transfer of momentum, mass and information

An alternate description of the course:

Properties of fluids, solids & mixtures

Distinguishing properties of the material from properties of the moving flow of material

Relies on continuum mechanics, which are often omitted from physics curricula and found mainly in graduate engineering courses

We live in a fluid and need to understand how it behaves, e.g., in a hurricane or tornado

Course Content

- Ecological design "problems" and "solutions" (a little teleological)
- Momentum transfer (getting around in and not getting clobbered by the flow)
- Mass transfer (getting enough of a specific kind of material, e.g., for maintenance, growth or reproduction)
- Information transfer (e.g., predator↔prey)

The course with the ugly title

- "Life in moving fluids" is taken.
- Relative to Vogel, a greater focus on low Reynolds numbers (small organisms and slow velocities)
- A greater focus on mass and information transfer
- Much less focus on drag

Course Approach

- Gain experience in flows around organisms
- Words (Blah, blah, blah; spoken and written by both you and me)
- Graphs & pictures (1 picture = 10^3 words)
- Equations
- Use any combination to answer questions, get extra credit and take no risk by using equations (B.F. Skinner)

Typical Day in Class

- Before the first midterm, morning laboratory, building on prior week's lecture (0830???)
- Afternoon lecture, background for the next lab (1330)
- More bias toward lectures & theory as the weather gets colder

Today

- Short Lecture (Basic terms and concepts)
- Short Lab (Material properties)
- Regular Lecture (Reynolds numbers)

Equations & Dimensions

- In this class, all equations **should** be dimensionally homogeneous.
- Every term has the same dimensions.
- For example, $F = m\ a$, so the dimensions of a force are $M\ L\ T^{-2}$ <http://physics.nist.gov/cuu/Units/units.html>.
- **Caution:** Many equations in biology are **not** dimensionally homogeneous

Dimensions vs. Units

- Dimensions are general and do not change with the system of measurement.
- Mass, Length, Time and Number [M,L,T,N] used in this class (a few others in the sensory section); one kind of N system is a mole = 6.022×10^{23}
- Units vary with the "yardstick" (e.g., lb, g, kg).
- Confession: I think in cgs, not SI, but the handouts and lectures will be in SI units.

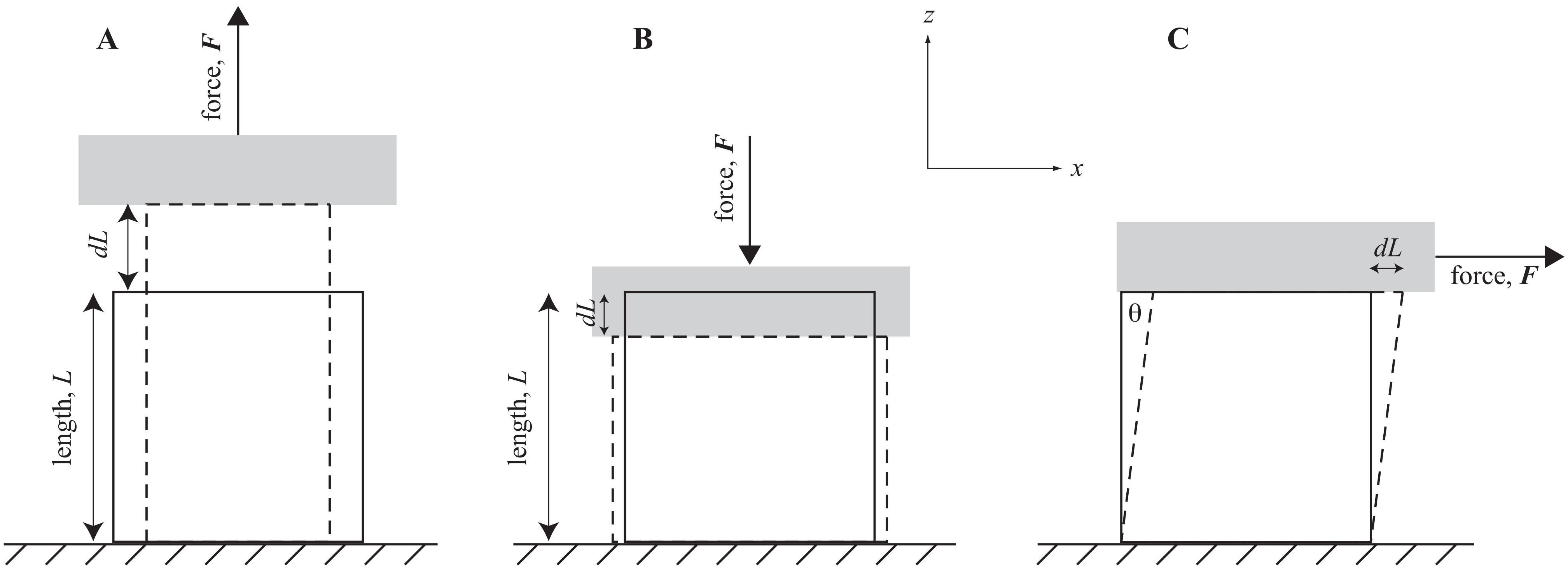
Stress & Strain in Ideal Liquids and Solids

- Stress is a force per unit of area
- In an ideal (Newtonian) liquid, constant stress produces constant **rate of strain or deformation (flow)**

- Strain is deformation in response to that force
- In an ideal (Hookean) solid, constant stress produces constant **strain (deformation)**

Note how refreshingly clear their definitions are in physics!

Stresses & Strains

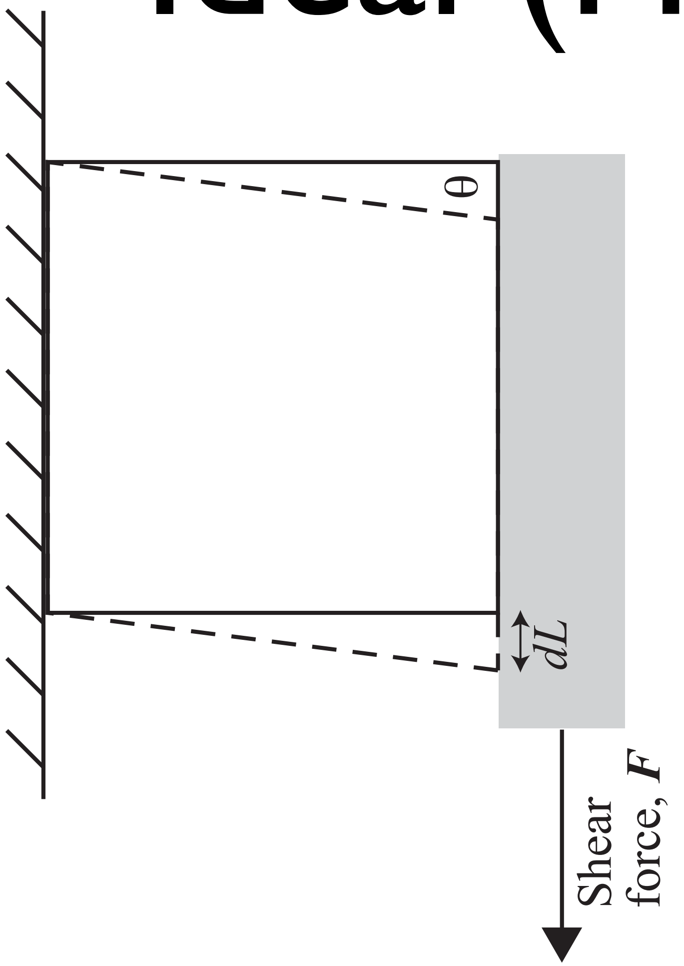


Tensile Compressive Shear

All uniaxial (one direction only)

Convention makes tensile stresses positive and compressive stresses negative.

Ideal (Hookean) solid



S = surface area

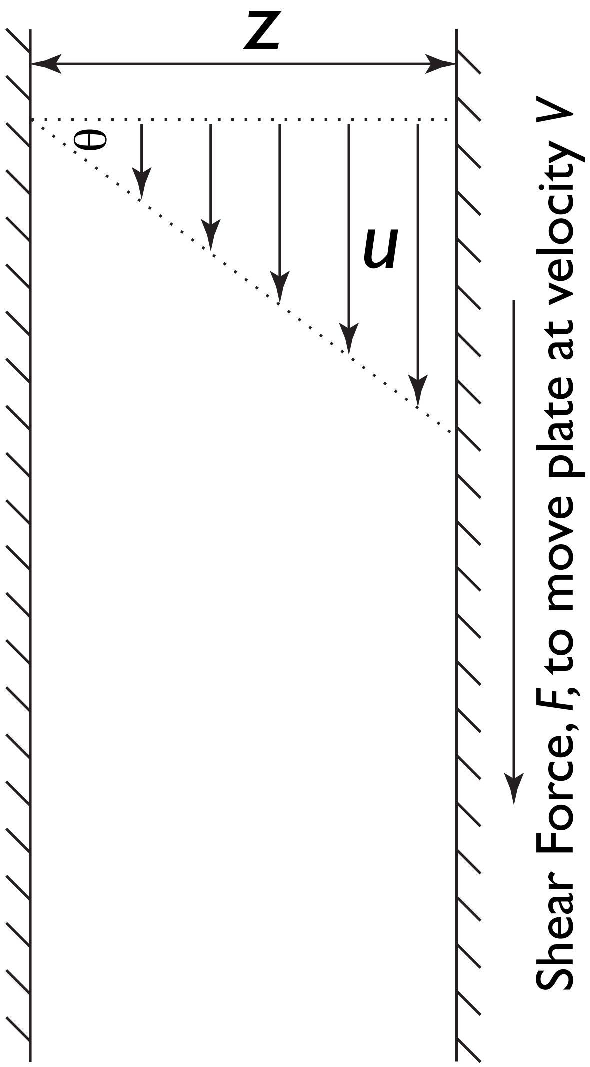
τ = Shear stress = F/S

$F/S = G\theta$

For an ideal solid,
G is a constant

Constant force produces constant deformation

Ideal (Newtonian) fluid flowing in a small gap, z, at low velocity



S = surface area

τ = shear stress = F/S =

$\mu\, du/dz = \mu\, V/z$

$F/S = \mu\theta/t$

μ = dynamic viscosity

For an ideal liquid,
μ is a constant

Constant force produces constant rate of deformation

Digression on oceanographic convention

- Eulerian coordinate system for flows has *x* as the downstream direction, *y* as the cross-stream direction and *z* as the vertical direction.
- The corresponding velocities are denoted, respectively, *u*, *v*, and *w*.
- Vogel generally uses an upper case *U* for the oceanographic *u*.
- Most engineering texts, but not all, now follow the same convention (*u*, *v*, *w*).

Pressure

- Normal force per unit of area
- Hydrostatic pressure (determined by height of the overlying column of fluid)
- At a point in a fluid, it has the same magnitude in all directions
- But there are other kinds of pressure produced by fluid motion

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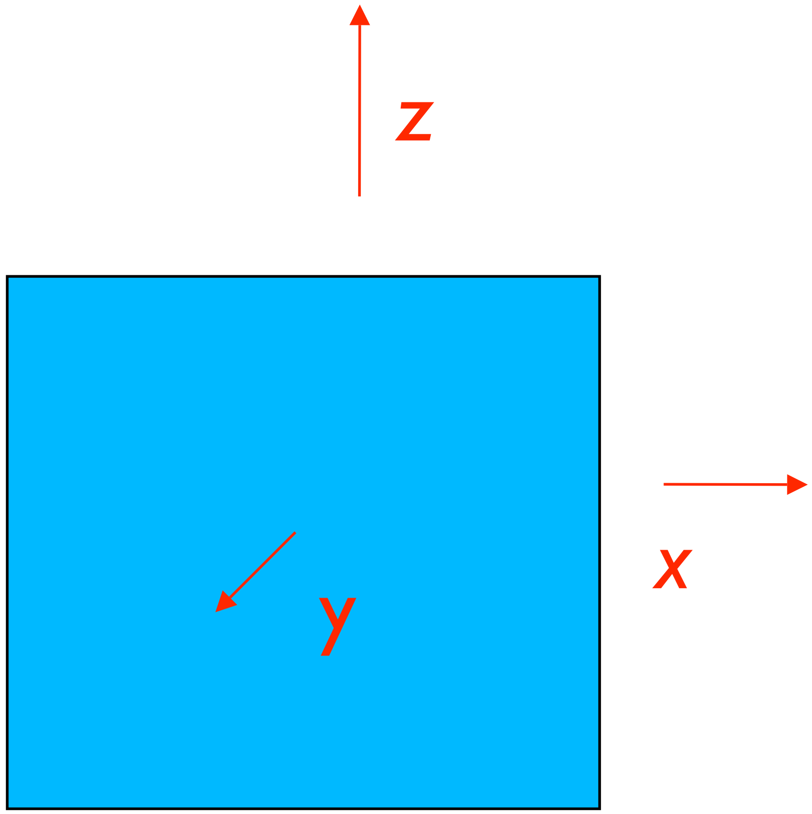
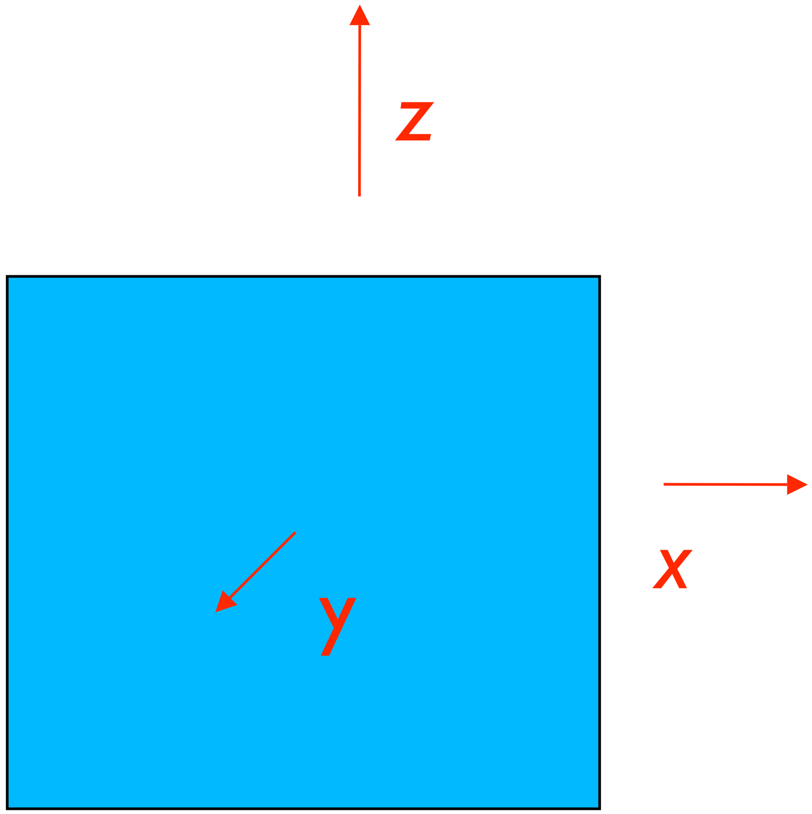
Force at a point



Force at a point

Each face of a cube has two tangential components and one normal component



Force at a point

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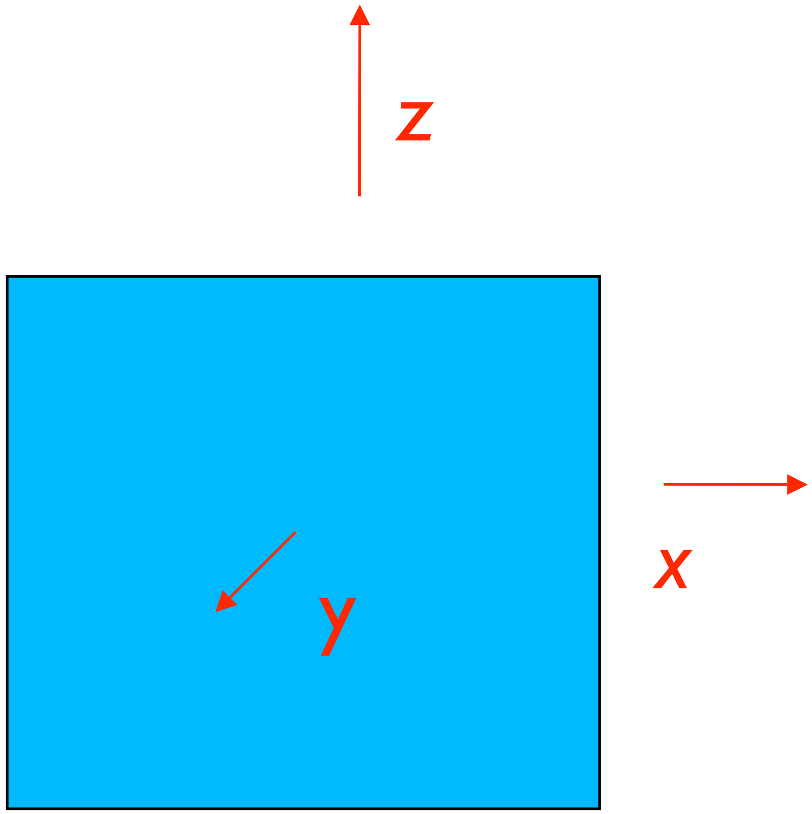
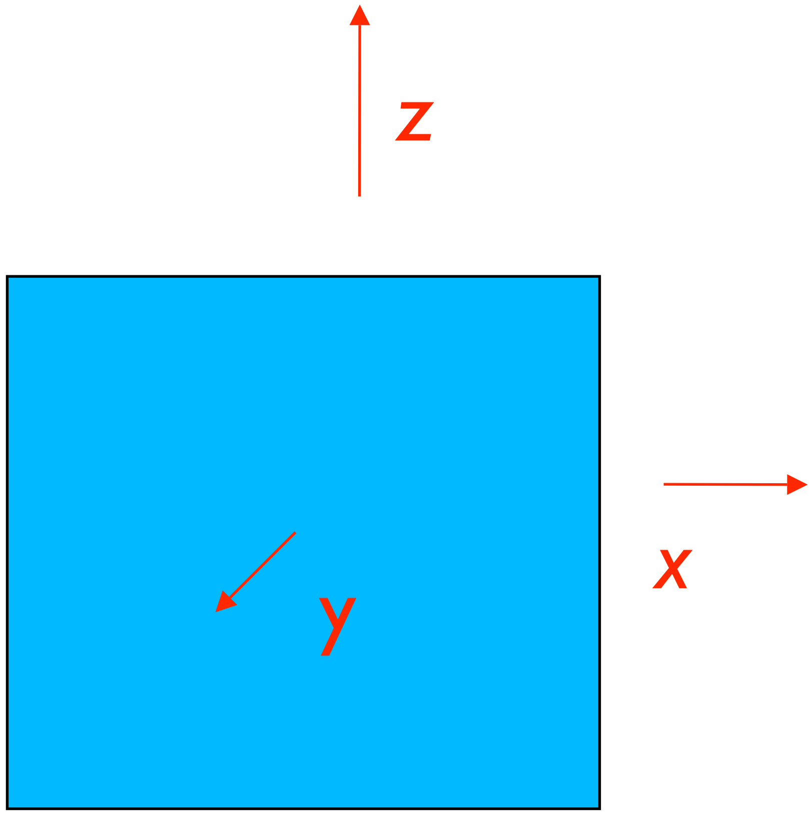


Net force can be summarized by 9 components, 3 on each face.

Force at a point

Each face of a cube has two tangential components and one normal component



Why don't we need the other three faces?

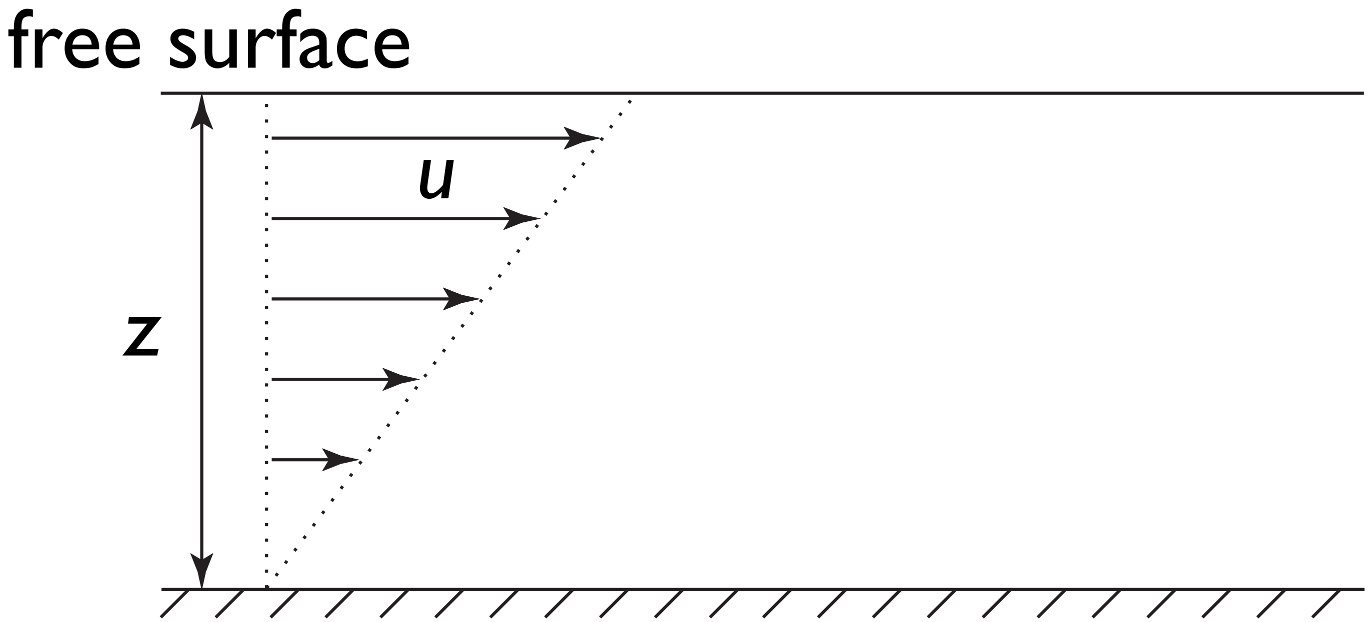
Net force can be summarized by 9 components, 3 on each face.

A digression

- Fluid dynamicists often call an infinitessimal parcel of water a "particle."
- This practice causes no end of confusion about real particles (solid objects in flows).
- Most physical oceanographers and fluid dynamicists do not work with real particles in flows.

More shear fun

- Shear has dimensions of inverse time [T^{-1}]
- Velocity (difference)/Distance = $(L T^{-1})/L = T^{-1}$
- This shear is vertical



How is force transmitted?

- In an ideal, viscous fluid, shear is transmitted by viscous forces (friction between layers of molecules).
- Normal forces in an ideal fluid are transmitted by various kinds of pressure.
- How are normal and tangential forces transmitted in solids and in granular materials?