Properties of water

How water interacts with the environment

Lecture outline

- Chemical and physical properties
- Viscosity, inertia, and critters
- Water in motion

Why is water so funky?

Polar covalent bond

Unique properties of water

<table>
<thead>
<tr>
<th>Property</th>
<th>Comparisons with other substances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>Max @ 4°C, not at freezing pt (actually expands)</td>
</tr>
<tr>
<td>Melting &amp; boiling points</td>
<td>Very high</td>
</tr>
<tr>
<td>Heat capacity</td>
<td>Very high</td>
</tr>
<tr>
<td>Heat of vaporization</td>
<td>Very high</td>
</tr>
<tr>
<td>Surface tension</td>
<td>High</td>
</tr>
<tr>
<td>Absorption of radiation</td>
<td>Minimum in visible region; ↑ red, infrared, &amp; UV</td>
</tr>
<tr>
<td>Solvent properties</td>
<td>Excellent for ionic/polar molecules</td>
</tr>
</tbody>
</table>

Table 2.1

Density vs. temperature

- Ice
- Stratification

Density = 0.917 g/ml @ 0°C
Density = 1 g/ml @ 3.98°C

Another view

Do the relative differences in density matter?
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Viscosity and inertia

- Viscosity: resistance of a fluid to change in form; internal friction
- Inertia: resistance of a body to a change of motion (i.e., acceleration or deceleration)
- As spatial scale shrinks, viscosity ↑ and inertia ↓
  - In small spaces or with very small organisms the force of individual water molecules is very important

Putting viscosity and inertia together

- Reynolds number

$$ Re = \frac{F_i}{F_v} $$

<table>
<thead>
<tr>
<th>Thingy</th>
<th>Re</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterium swimming</td>
<td>0.000001</td>
</tr>
<tr>
<td>Pollen grain falling or sperm swimming</td>
<td>0.01</td>
</tr>
<tr>
<td>Fruit fly in flight</td>
<td>100</td>
</tr>
<tr>
<td>Small bird flying</td>
<td>100,000</td>
</tr>
<tr>
<td>Squid fast jetting</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Large whale swimming</td>
<td>200,000,000</td>
</tr>
</tbody>
</table>

Implications of $Re$ for organisms of different sizes

- Comparing a rotifer to a trout:
  - Who can move easier?
  - Who can collect food easier?
  - Who can get oxygen easier?
  - Who can get rid of wastes easier?

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Laminar vs. turbulent flow

- **Laminar flow**: fluid moves primarily in one direction and uniformly, little mixing (diffusion), viscosity dominates
  - In streams: parallel ‘layers’ sliding past one another
  - Re < 10
- **Turbulent flow**: fluid moves chaotically with much mixing, eddies forming, viscosity less important
  - Re > 2000

Streamlining and Re

- A. Laminar
  - Re < 5

- B. Vortices
  - 5 < Re < 100,000

- C. Fully turbulent
  - >100,000 Re

- D. Laminar
  - Re < 20

- E. Few vortices
  - 20 < Re < 100,000

- F. Vortices to fully turbulent flow >100,000 Re

Flow boundary layer

- Water slows and becomes more laminar as it nears a solid surface due to friction; = 'No-slip condition'
- The thickness of the boundary layer extends to where flow is not influenced by the solid surface (99% of open channel velocity)

Visuallyizing more turbulence

Where do most stream organisms live?

- Is there anything about this habitat that is especially important for these organisms?

Flow boundary layer (3)

- Vogel (1988) points out that people “retain a fuzzy notion that the boundary layer is a discrete region of nonmoving fluid rather than the discrete notion that the boundary layer is a fuzzy region in which there is a strong velocity gradient”
Interesting ways to feed associated with turbulence (1)

Black flies feeding

Interesting ways to feed associated with turbulence (2)

- Vortex feeding...filtering

Fig. 2. Diagram of feeding by *A. nervosus* novel larvae. Arrows indicate the direction of flow as observed from the surface. For clarity, only flow from near the bottom and at the level of the claws (0-5 mm above the bottom) is depicted. Drawing is a composite image based on analysis of videotapes and still photographs.

Soluk & Craig (1988)

Interesting ways to feed associated with turbulence (3)

- Vortex feeding...predation

Fig. 3. Diagrammatic representation of feeding behavior of *P. centrallis*. Arrows indicate direction of flow. Larva in archd position creates a solenoidal vortex that spins out lateraally on both sides of the head. The vortex rapidly spreads sand from under the mouthparts, forming a pit (A) in which the *P. centrallis* larva probes for the small, immotile chironomids on which it feeds. Subsequent backward movement of larva expands the pit (B) temporarily leaving a shallow groove on the face of the dune.

Soluk & Craig (1990)