Drop Quiz 1

Given a fluid particle of density ρ and volume $\delta\mathcal{V}$ moving with a velocity $\mathbf{u}$, what are the forces acting on it?

Solution
Newton's second law applied on the particle is

$$\sum \mathbf{F} = \frac{d}{dt}(\rho\,\delta\mathcal{V}\,\mathbf{u})$$

Since the particle is a control mass, the conservation of mass is expressed as

$$\frac{d}{dt}(\rho\,\delta\mathcal{V}) = 0$$

Newton's second law is then

$$\sum \mathbf{F} = \rho\,\delta\mathcal{V}\,\frac{d\mathbf{u}}{dt}$$

where the forces acting on the particle are:

- weight (body force) given by $\rho\,\delta\mathcal{V}\,\mathbf{g}$, where $\mathbf{g}$ is gravity.

- pressure force (surface force) acting on the surface of the particle given by $-\nabla p\,\delta\mathcal{V}$. This is obtained by integrating the pressure force per unit area on the surface $-p\hat{\mathbf{n}}\,dA$ over the control surface.

- viscous force (surface force): this will be covered later in the course

- surface tension (line force) if part or all of the control surface is an interface with another fluid or phase, given by $\int_\Pi \gamma\hat{\mathbf{s}}\,dl$ where Π is the perimeter of the interface between the two fluids, $\hat{\mathbf{s}}$ is the unit vector tangent to the interface, and γ is surface tension.