# 1 Key Concepts

- Conservation of Mass, Energy, and Momentum
- Line Integrals
- Integrals in polar, cylindrical, and spherical coordinates

# 2 Important Equations

$$M = \int_V \rho dV \qquad \text{(Formulation of Mass)}$$

$$\frac{dM}{dt} = \int_S \rho \overrightarrow{u} \cdot \overrightarrow{n} dS \qquad \text{(Conservation of Mass)}$$

$$\frac{dM}{dt} = \dot{m}_{in} - \dot{m}_{out} \qquad \text{(Conservation of Mass (simple))}$$

$$H = \frac{v^2}{2} + \overrightarrow{g} \cdot \overrightarrow{r} + \frac{p}{\rho} \qquad \text{(Bernoulli's Equation)}$$

$$dV = \rho^2 sin(\phi) d\phi d\theta d\rho \qquad \text{(Differential Volume in Spherical Coordinates)}$$

# 3 Practice Problems

1. Derive the integral conservation of mass equation.
2. Derive the integral conservation of momentum equation.
3. Evaluate the line integral $\int_C (1 + xy^2)ds$ from (0,0) to (1,2) along the curve $C$ given by parametric equations $x = t$ and $y = 2t$.
4. An ideal fluid travels through a pipe of diameter $D_1$ at position $z_1$ with average velocity $v_1$. What is the change in pressure experienced by the fluid as it travels up the pipe to an elevation $z_2$ with a new diameter $D_2$? What is the change in velocity? What is the mass flow rate?
5. Suppose there is a gas giant planet whose density changes with a constant $k$ of its depth. If the planet has an outer radius $R$, and and an internal density $\rho_0$, then what is its total mass?