Chapter 3
Conservation Laws

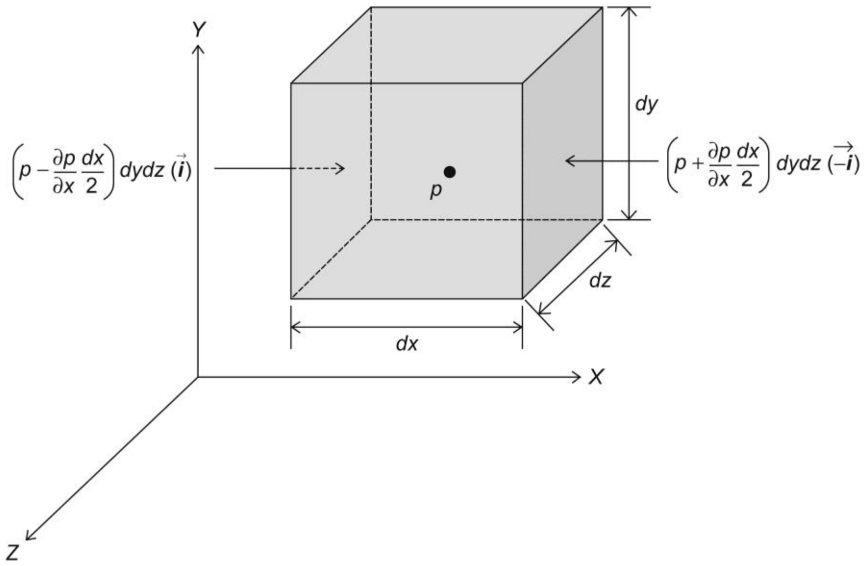

Figure 3.1 *X*-direction pressure forces that act on a differential fluid element. The same pressure forces can be derived for the other Cartesian directions.

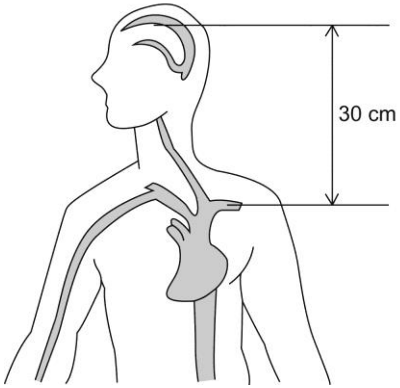

Figure 3.2 Difference in fluid static pressure between the aortic valve and the cranium based on height.

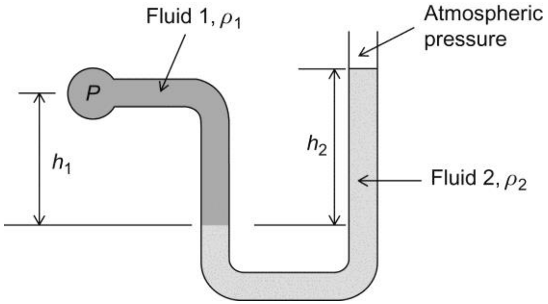

Figure 3.3 Schematic of a classic fluid mechanics manometer for measuring the pressure of a fluid at *P*. By measuring the differences in height, with a known open pressure, the hydrostatic pressure at *P* can be calculated.

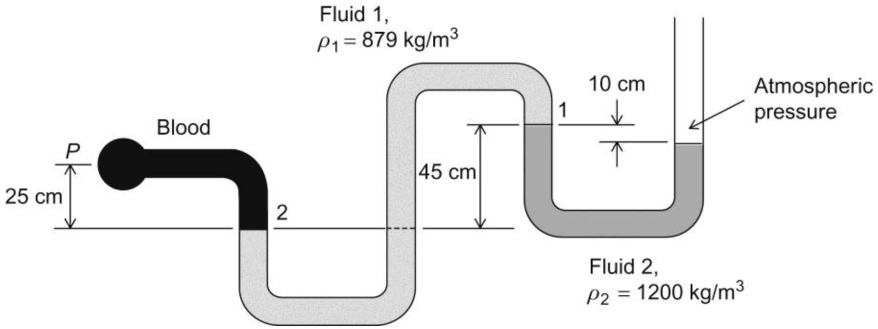

Figure 3.4 Schematic of a catheter tip manometer to measure intravascular blood pressure.

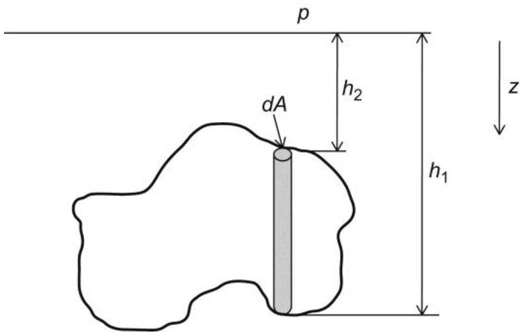

Figure 3.5 A body immersed in a static fluid. *dA* describes the cross-sectional area of the body at the location of h_1 and h_2 (which are measured in the *z*-axis). Various cross-sectional areas would be used to determine the buoyancy forces on an immersed object.

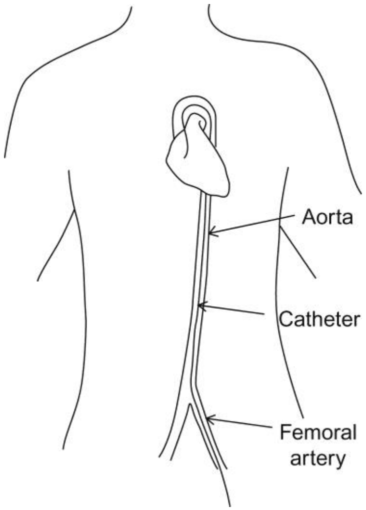

Figure 3.6 Catheter inserted at the femoral artery which is passed to the coronary artery. These catheters are commonly used during surgeries to remedy atherosclerotic lesions.

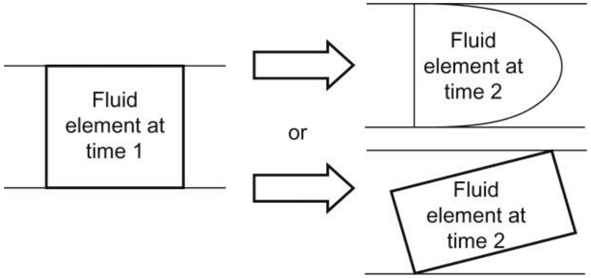

Figure 3.7 Two possible arrangements for a fluid element after the fluid experienced some motion. It is easier to maintain the control volume square of time 1 to analyze the fluid, instead of changing the volume of interest with time. This image shows that there are multiple possible arrangements for fluid elements after deformation, depending on the boundary conditions. It is critical during the analysis of biofluid mechanics problems to simplify these issues of deformability by choosing control volumes wisely.

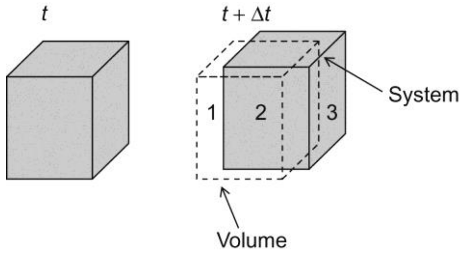

Figure 3.8 System and volume of interest used to derive the formula for conservation laws. The system of interest is shown by the gray shaded cube, and the volume of interest is the dashed cube. To use this formulation, one would need to know the change in time between the two states shown in this figure.

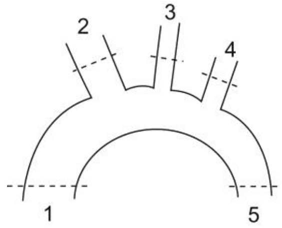

Figure 3.9 Schematic of the aortic arch.

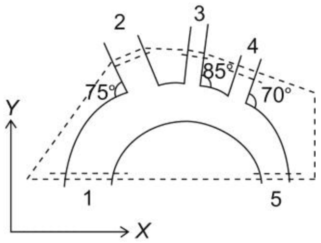

Figure 3.10 Figure depicting our choice for the control volume around the aortic arch. Notice that the area of interest at each location (1–5) are perpendicular to the mean velocity direction.

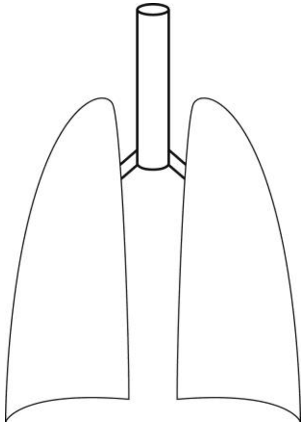

Figure 3.11 Schematic of the lung.

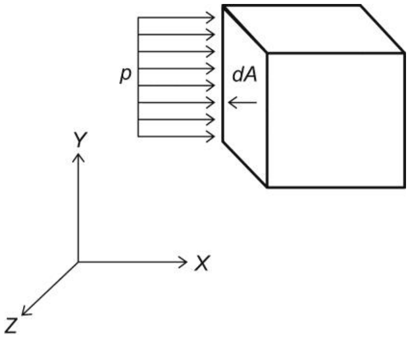

Figure 3.12 Pressure force acting on a surface of interest. Recall that the area vector for this surface would act in the negative *x*-direction, whereas the pressure forces are acting in the positive*x*-direction.

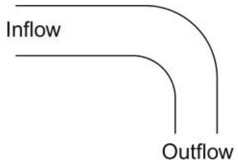

Figure 3.13 Brachial artery schematic for example problem.

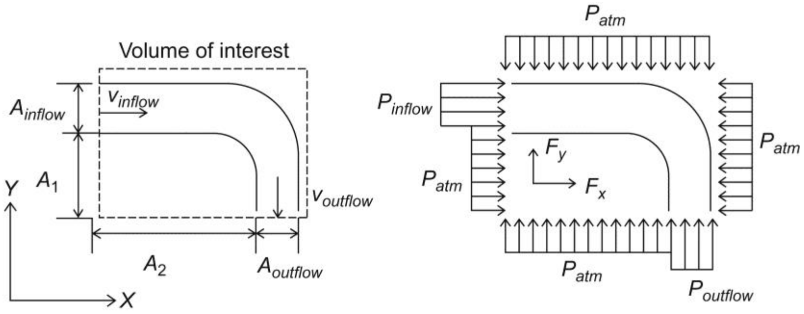

Figure 3.14 Free body diagram for the brachial artery example problem.

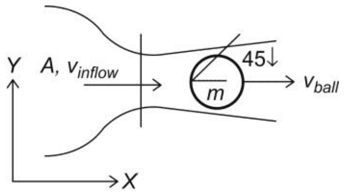

Figure 3.15 Acceleration of a ball and cage mechanical heart valve for the in-text problem.

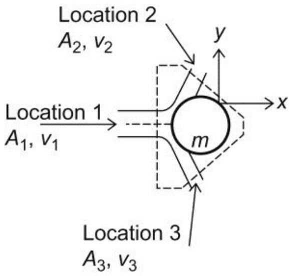

Figure 3.16 Free body diagram for ball and cage mechanical heart valve example problem.

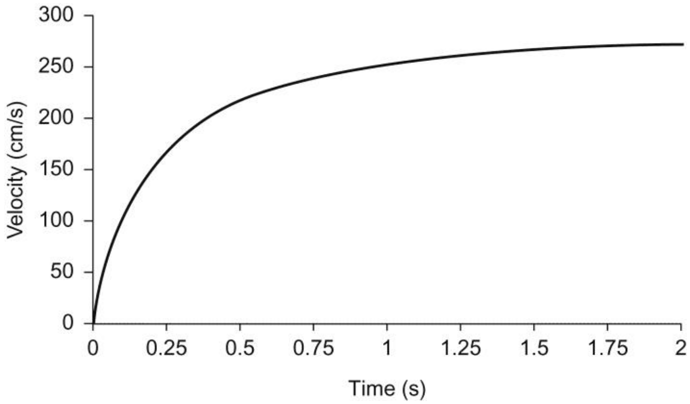

Figure 3.17 Velocity of the ball with respect to time.

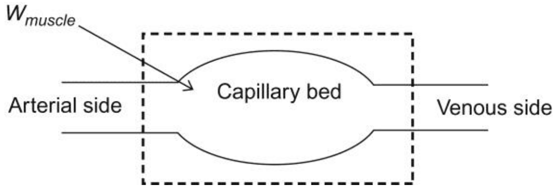

Figure 3.18 Schematic of a capillary heat exchanger for the example problem.

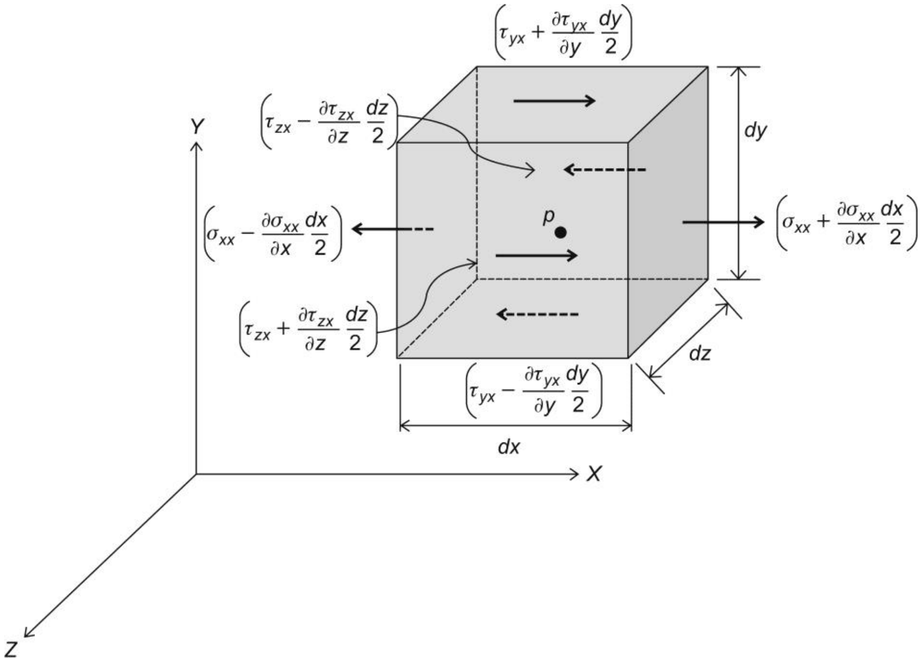

Figure 3.19 The normal and shear stresses acting in the$x$-direction on a differential fluid element. The stresses that act in the other Cartesian directions can be derived in a similar manner. Recall that only six of these stress values are independent for momentum conservation.

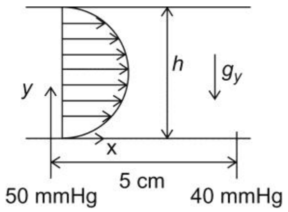

Figure 3.20 Pressure-driven flow in an arteriole for example problem.

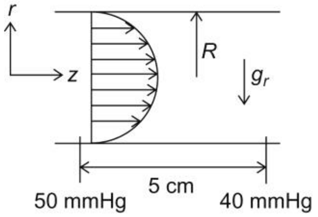

Figure 3.21 Pressure-driven flow in an arteriole with cylindrical coordinates for the in-text example. This is the same image as Figure 3.20, but choosing a different coordinate system to illustrate the usage of Cartesian coordinates versus cylindrical coordinates.

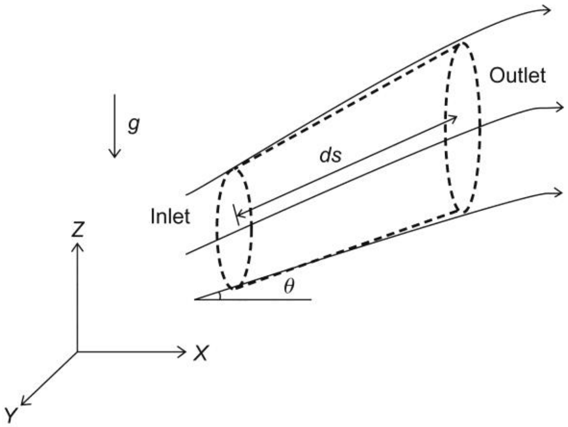

Figure 3.22 A differential volume of fluid following expanding streamlines (streamlines are the curved arrows in the figure). The expansion causes an increase in area at the outlet as compared to the inlet.

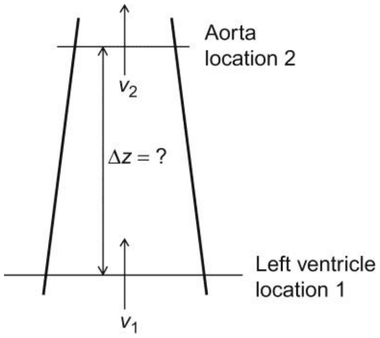

Figure 3.23 Schematic of the aorta downstream to the left ventricle. The aorta would experience a slight contraction within this area.

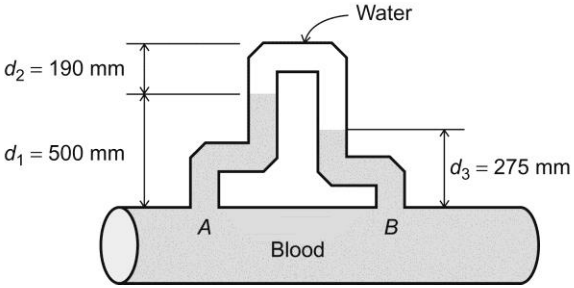

Figure 3.24 Figure for Homework Problem 3.1.

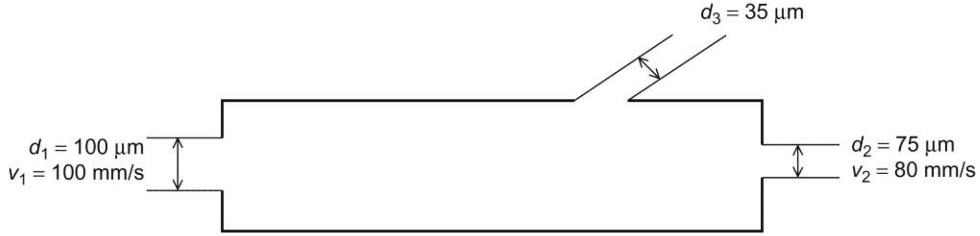

Figure 3.25 Figure for Homework Problem 3.5.

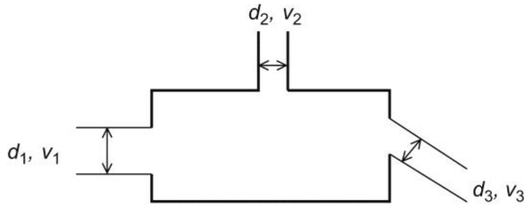

Figure 3.26 Figure for Homework Problem 3.7.

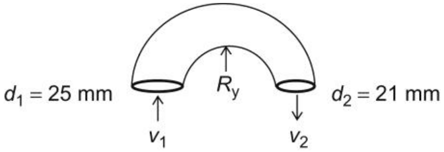

Figure 3.27 Figure for Homework Problem 3.10.

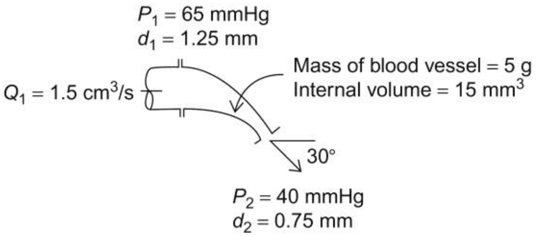

Figure 3.28 Figure for Homework Problem 3.11.

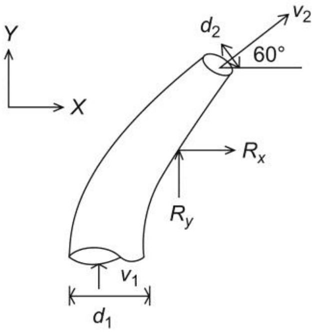

Figure 3.29 Figure for Homework Problem 3.12.

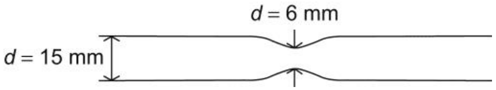

Figure 3.30 Figure for Homework Problem 3.16.

Figure 3.31 Figure for Homework Problem 3.17.

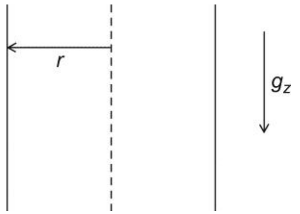

Figure 3.32 Figure for Homework Problem 3.19.

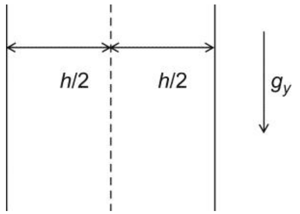

Figure 3.33 Figure for Homework Problem 3.20.

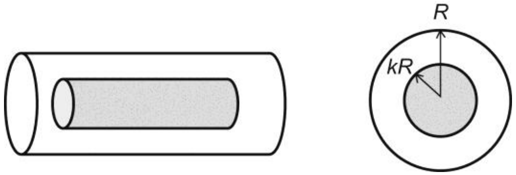

Figure 3.34 Figure for Homework Problem 3.21.

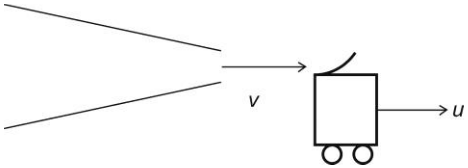

Figure 3.35 Figure for Homework Problem 3.23.

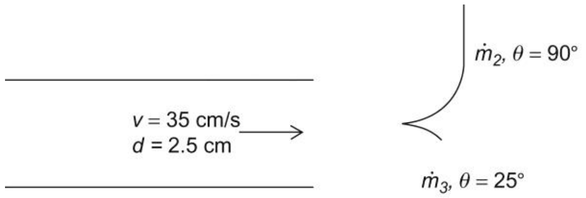

Figure 3.36 Figure for Homework Problem 3.26.