A 4-ft-high, 3-ft-diameter cylindrical water tank whose top is open to the atmosphere is initially filled with water.(We could also treat this as a fixed control volume that consists of the interior volume of the tank by dis?regarding the air that replaces the space vacated by the water.) This is obvi?ously an unsteady-flow problem since the properties (such as the amount of mass) within the control volume change with time. 185-242_cengel_ch05.indd 193 12/17/12 10:55 AM 194 BERNOULLI AND ENERGY EQUATIONS Canceling the densities and other common terms and separating the vari?ables give dt 5 2D2 tank D2 jet dh "2gh Integrating from t 5 0 at which h 5 h0 to t 5 t at which h 5 h2 gives # t 0 dt 5 2 D2 tank D2 jet"2g # h2 h0 dh "h S t 5 "h0 2 "h2 "g/2 a Dtank Djet b 2 Substituting, the time of discharge is determined to be t 5 "4 ft 2 "2 ft "32.2/2 ft/s2 a 3 3 12 in 0.5 in b 2 5 757 s 5 12.6 min Therefore, it takes 12.6 min after the discharge hole is unplugged for half of the tank to be emptied. Discussion Using the same relation with h2 5 0 gives t 5 43.1 min for the discharge of the entire amount of water in the tank. Therefore, emptying the bottom half of the tank takes much longer than emptying the top half. This is due to the decrease in the average discharge velocity of water with decreasing h. 5-3 ? MECHANICAL ENERGY AND EFFICIENCY Many fluid systems are designed to transport a fluid from one location to another at a specified flow rate, velocity, and elevation difference, and the system may generate mechanical work in a turbine or it may con?sume mechanical work in a pump or fan during this process (Fig. 5-14).in 5 0), and the mass flow rate of discharged water is m # out 5 (rVA)out 5 r"2ghAjet (2) where Ajet 5 pD2 jet/4 is the cross-sectional area of the jet, which is constant. Noting that the density of water is constant, the mass of water in the tank at any time is mCV 5 rV 5 rAtankh (3) where Atank 5 pD2 tank/4 is the base area of the cylindrical tank. Substituting Eqs. 2 and 3 into the mass balance relation (Eq. 1) gives 2r"2ghAjet 5 d(rAtankh) dt S 2r"2gh(pD2 jet /4) 5 r(pD2 tank/4)dh dt Water Air 0 Dtank Djet h2 h0 h FIGURE 5-13 Schematic for Example 5-2.Then the mechanical energy change of a fluid during incompressible flow becomes Demech 5 P2 2 P1 r 1 V 2 2 2 V 2 1 2 1 g(z2 2 z1) (kJ/kg) (5-24) Therefore, the mechanical energy of a fluid does not change during flow if its pressure, density, velocity, and elevation remain constant.An ideal hydraulic turbine at the bottom elevation would produce the same work per unit mass wturbine 5 gh whether it receives water (or any other fluid with constant density) from the top or from the bottom of the container.Because of irreversibilities such as friction, mechanical energy cannot be converted entirely from one mechanical form to another, and the mechanical efficiency of a device or process is defined as hmech 5 Mechanical energy output Mechanical energy input 5 Emech, out EFlow work is expressed in terms of fluid properties, and it is convenient to view it as part of the energy of a flowing fluid and call FIGURE 5-14 Mechanical energy is a useful concept for flows that do not involve significant heat transfer or energy conversion, such as the flow of gasoline from an underground tank into a car.Therefore, the mechanical energy of a flowing fluid can be expressed on a unit-mass basis as emech 5 P r 1 V 2 2 1 gz where P/r is the flow energy, V2/2 is the kinetic energy, and gz is the poten tial energy of the fluid, all per unit mass.The average velocity of the jet is approximated as V 5 !2gh, where h is the height of water in the tank measured from the center of the hole (a variable) and g is the gravitational acceleration.3 The gravitational acceleration is 32.2 .ft/s2.5-13).5-15