QUIZ #1 SOLUTIONS

QUIZ #1A MULTIPLE CHOICE

MULTIPLE CHOICE SECTION, PROBLEMS 1-5 [1 POINT EACH]

(1) A system which has neither mass nor energy transfer across the boundary is called a(n):
(A) Closed System
(B) Open System
(C) Isolated System
(D) None of the above

(2) The zeroth (0^{th}) law of thermodynamics states that:
(A) Energy is conserved.
(B) If two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.
(C) A system undergoes a cycle if it returns to its initial state at the end of a process
(D) None of the above

(3) The total energy of a stationary system is equivalent to:
(A) The internal energy of the system
(B) The kinetic energy of the system
(C) The potential energy of the system
(D) The sum of the kinetic and potential energies of the system.

(4) Which of the following is NOT a type of internal energy associated with the microscopic forms of energy in a system?
(A) sensible energy
(B) latent energy
(C) chemical energy
(D) mass flow energy

(5) For a cycle (a system's initial state is the same as the final state), the work done is equivalent to:
(A) The distance travelled by the system
(B) The change in temperature of the system
(C) The heat added to the system
(D) None of the above

QUIZ #1B MULTIPLE CHOICE

MULTIPLE CHOICE SECTION, PROBLEMS 1-5 [1 POINT EACH]

(1) A system which has both mass and energy transfer across the boundary is called a(n):

(A) Closed System
(B) Open System
(C) Isolated System
(D) None of the above

(2) The zeroth (0^{th}) law of thermodynamics states that:

(A) Energy is conserved.
(B) If two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.
(C) A system undergoes a cycle if it returns to its initial state at the end of a process
(D) None of the above

(3) The total energy of a stationary system is equivalent to:

(A) The potential energy of the system
(B) The kinetic energy of the system
(C) The internal energy of the system
(D) The sum of the kinetic and potential energies of the system.

(4) Which of the following is NOT a type of internal energy associated with the microscopic forms of energy in a system?

(A) mass flow energy
(B) latent energy
(C) chemical energy
(D) sensible energy

(5) For a cycle (a system's initial state is the same as the final state), the work done is equivalent to:

(A) The distance travelled by the system
(B) The heat added to the system
(C) The change in temperature of the system
(D) None of the above

QUIZ #1A & QUIZ #1B Problems

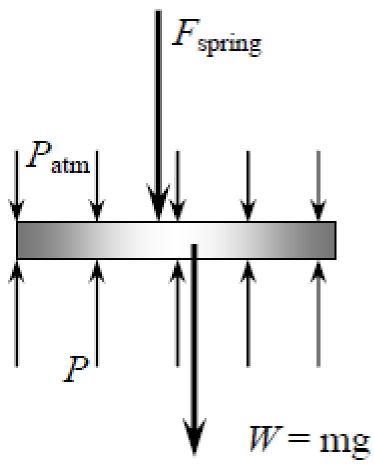
(6) **[6 POINTS]** A gas is contained in a vertical, frictionless piston–cylinder device. A compressed spring above the piston exerts a force of 100 N down onto the piston. The pressure of the gas inside the piston is 250 kPa absolute pressure, the atmospheric pressure outside is assumed to be 100 kPa, and the piston area is 40 cm^2.

(A) Draw a diagram of the system.

(B) Determine the mass of the piston.

(C) If the spring is removed and the system is allowed to reach equilibrium, what is the new pressure inside the cylinder?

(A)



(B) Based on a force balance of the piston:

$P_gA = P_{atm}A + W + F_{spring}$

$W = (P_g - P_{atm})A - F_{spring}$

$$W = (250\,kPa - 100kPA)(0.004m^2)\left(\frac{1000N/m^2}{1kPa}\right) - 100N$$

W = 500 N

$W = m_{piston}g$

$m_{piston} = W/g$

$m_{piston} = 500N/(9.81m/s^2)$

m_{piston} = 51 kg

(C) Based on a force balance of the piston:

$P_gA = P_{atm}A + W$

$P_g = P_{atm} + W/A$

$$P_g = 100kPa + \frac{500N}{0.004\,m^2}\left(\frac{1kPa}{1000N/m^2}\right)$$

P_g = 225 kPa

(7) **[6 POINTS]** A wind turbine is rotating at 16 rpm under steady winds flowing through the turbine at a rate of 45,000 kg/s. The tip velocity of the turbine blade is measured to be 260 km/hr. 180 kW of power is produced by combining the turbine with a generator. Assume the density of air is 1.31 kg/m^3.

(A) What is the average velocity of the air at the turbine blades?

(B) What is the overall conversion efficiency of the turbine-generator?

(C) If the generator has an efficiency of 80%, what is the efficiency of the turbine?

(A) $\dot{m} = \rho V_{ave} A$

$V_{ave} = \frac{\dot{m}}{\rho A}$

We are not provided the area. We need to solve for it.

$angular\ velocity\ = \frac{V_{tip}}{r}$

$$\frac{16\ revolutions}{minute}\left(\frac{1min}{60sec}\right)\left(\frac{2\pi\ radians}{1revolution}\right) = \frac{\frac{260km}{hr}\left(\frac{1hr}{3600sec}\right)\left(\frac{1000m}{1km}\right)}{r}$$

r = 43.1045 m

$A = \pi r^2 = \pi(43.1045)^2$

$A = 5{,}837m^2$

$V_{ave} = \frac{\dot{m}}{\rho A} = \frac{45{,}000kg/s}{(1.31kg/m^3)(5{,}837\ m^2)}$

$\boldsymbol{V_{ave} = 5.885m/s}$

(B) $\Delta\dot{E}_{mech} = \Delta KE = \frac{1}{2}\dot{m}V^2 = \frac{1}{2}(45{,}000kg/s)(5.885m/s)^2$

$\eta_{overall} = \frac{\dot{W}_{electric}}{\Delta\dot{E}_{mech}} = \frac{180kW}{779.25kW}$

$\eta_{overall}$ =0.231 =23.1%

(C) $\eta_{overall} = \eta_{turbine}\eta_{generator}$

$0.231 = \eta_{turbine}(0.80)$

$\eta_{turbine}$= 0.2888 = 28.88%

(8) **[8 POINTS]** Water is pumped from a lower reservoir to a higher reservoir by a pump that consumes 20kW of electrical power. The free surface of the higher reservoir is 45 meters above the lower reservoir. The flow rate of the water is measured to be 0.03 m^3/s. Assume the density of water to be 1,000 kg/m^3.

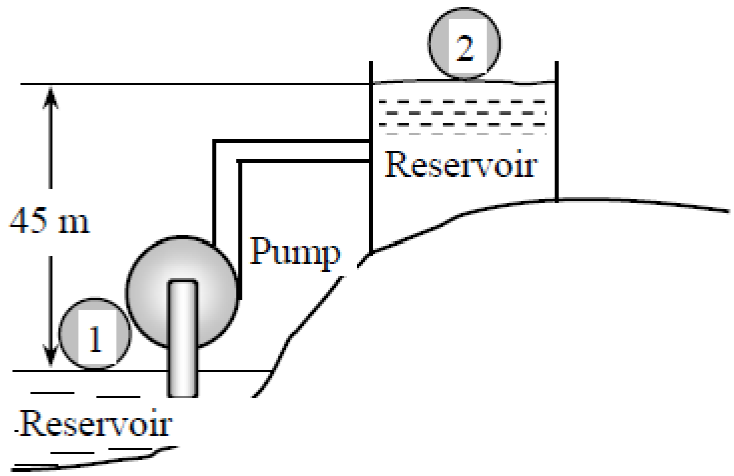
(A) Draw a diagram of the system

(B) Determine the mechanical power required to pump the water from the lower reservoir to the higher reservoir.

(C) What is the efficiency of the pump?

(D) Now assume that the pressure at the pump inlet is 101.3 kPa. What is the pressure at the exit of the pump?

(A)



(B)

$$\Delta \dot{E}_{mech} = \dot{m}\Delta e_{mech}$$

$$\Delta \dot{E}_{mech} = \dot{m}\left(e_{mech,out} - e_{mech,out}\right)$$

$$\Delta \dot{E}_{mech} = \dot{m}\left[\left(\frac{P}{\rho} + \frac{V^2}{2} + gz\right)_{out} - \left(\frac{P}{\rho} + \frac{V^2}{2} + gz\right)_{in}\right]$$

There are no changes in pressure or velocity between the system inlet and outlet. There are only changes in potential energy.

$$\Delta \dot{E}_{mech} = \dot{m}[(gz)_{out} - (gz)_{in}]$$

$$\Delta \dot{E}_{mech} = \rho \dot{V} g(z_{out} - z_{in})$$

$$\Delta \dot{E}_{mech} = (1000kg/m^3)(0.03m^3/s)(9.81m/s^2)(45m)\left(\frac{1N}{1kg*m/s^2}\right)\left(\frac{1kW}{1000N*m/s}\right)$$

$$\Delta \dot{E}_{mech} = \mathbf{13.2435\ kW}$$

(C) $\eta_{pump} = \frac{\Delta \dot{E}_{mech}}{\dot{W}_{electic}} = \frac{13.2435kW}{20kW}$

$\eta_{pump} = 0.6622$

$\boldsymbol{\eta_{pump} = 66\%}$

(D) Now, the control volume (system) is only the pump.

$$\Delta \dot{E}_{mech} = \dot{m}\left[\left(\frac{P}{\rho} + \frac{V^2}{2} + gz\right)_{out} - \left(\frac{P}{\rho} + \frac{V^2}{2} + gz\right)_{in}\right]$$

We can assume that there are no kinetic or potential energy changes in across the pump.

$$\Delta \dot{E}_{mech} = \dot{m}\left[\left(\frac{P}{\rho}\right)_{out} - \left(\frac{P}{\rho}\right)_{in}\right]$$

$$\Delta \dot{E}_{mech} = \dot{V}(P_{out} - P_{in})$$

$$(P_{out} - P_{in}) = \frac{\Delta \dot{E}_{mech}}{\dot{V}}$$

$$(P_{out} - P_{in}) = \left(\frac{13.2435kW}{0.03m^3/s}\right)\left(\frac{1000Nm}{kW * s}\right)\left(\frac{1kPa * m^2}{1000N}\right)$$

$$(P_{out} - P_{in}) = 441.45kPa$$

$$P_{out} = 441.45kPa + P_{in} = 441.45kPa + 101.3kPa$$

$$\boldsymbol{P_{out} = 543kPa}$$