MAE3310-001
Spring 2009
Feb 19, 2009

Name: SOLUTION

a. Closed book examination. No reference materials allowed.
b. Duration of test is 60 minutes.
c. Show all steps and equations in your calculations for partial credits.
d. Use data provided in the problems.
e. **Following definitions apply:**
   a. Specific gravity = Ratio of density of fluid to that of water
   b. Gravity constant = 9.81 m/s^2 where not provided.
   c. Atmospheric pressure = 100 kPa where not provided.
   d. 1 kg/l = 1000 kg/m^3; 1 Pa = 1 N/m^2; 1 N = 1 $kg.m/s^2$;
   e. Write all the units.

1. Consider a class room that is initially at the outdoor temperature of 20°C. The room contains eight 60-W light bulbs, a 360-W desktop computer, and a 200-W projector. The room is required to be fitted with a window air conditioning unit to keep the room at the outdoor temperature of 20°C.

$$Q_{LOAD} = 8 \times 60 + 360 + 200$$

Design Cooling Load = $\boxed{1040 \text{ W}}$

2. An adiabatic closed system is raised 100 m at a location where the gravitational acceleration is 9.8 m/s^2. Determine the change of energy of this system in kJ/kg.

$$\Delta E = \Delta PE$$

$$= \frac{(100)(9.8)}{1000} = 0.98 \frac{kJ}{kg}$$

Energy change of the system $\boxed{0.98 \text{ kJ/kg}}$

3. The atmospheric pressures at the top and the bottom of a building are read by a barometer to be 96.0 and 98.0 kPa. If the density of the air is 1.0 kg/m^3, find the height of the building in meters.

$$\Delta P = \rho_{air} \cdot h \cdot g / 1000$$

$$2 = \frac{(1.0)(h)(9.8)}{1000}$$

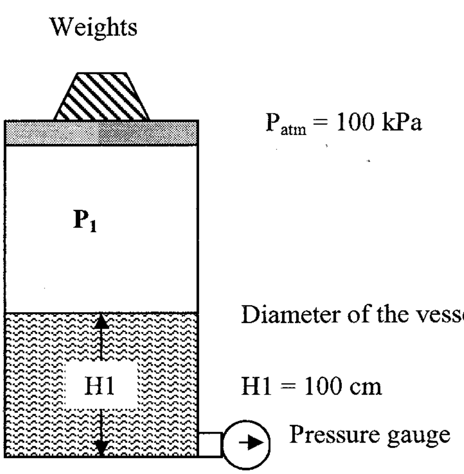
$$h = \frac{2000}{9.8}$$

Height of the building in meters $\boxed{\cong 204 \text{ m}}$

4. Consider an industrial pressure cooker shown here as a cylinder/piston system for modeling purposes. This cooker is to be used at various temperatures for proper cooking of the materials by adding weights on the pan. Assume that the properties of water are not changed by the vegetables in the cooker and the dimensional information as provided in the schematic.

Water properties required for calculations.

Temp °C	Pressure, kPa
120	198.7
130	270.28



P_{atm} = 100 kPa

Density of water= 1kg/l

Specific gravity of Mercury = 13.6

Diameter of the vessel= 100 cm

H1 = 100 cm

a. The cooker is initially with water to a height of 100 cm and is to be used to cook vegetables at 120°C and this requires no additional weights other than the weight of the piston. Estimate the pressure as indicated by the pressure gage attached to the bottom of the cooker in kPa.

$$P_2 = P_1 + \frac{H_1 \rho g}{1000}$$

$$= 198.7 + \frac{(1)(1000)(9.8)}{1000} = 208 \text{ kPa}$$

Pressure gage reading $\boxed{208 \text{ kPa}}$

b. If the pressure gage were to be replaced by a mercury manometer in problem a, what is the height of the mercury column in mm of mercury in that manometer?

$$108 = \frac{h_{Hg} \rho_{Hg} g}{1000}, \quad h_{Hg} \text{ in m}$$

$$h = \frac{1\cancel{000} \times 108}{136\cancel{00} \times 9.\cancel{8}}$$

Height of the mercury $\boxed{\simeq 770 \text{mm}}$

c. What is the mass of the piston (no weights initially) in kg?

$$A = \frac{\pi D^2}{4} \simeq 0.75 \text{ m}^2$$

$$(P_1 - P_{atm}) A = \frac{mg}{1000}$$

$$(98.7)(0.75) = \frac{(m)(9.8)}{1000}$$

$$m = 10 \times 0.75 \times 1000$$

$$= 7{,}500 \text{ kg}$$

Mass of the piston $\boxed{\simeq 7{,}500 \text{ kg}}$

d. It is required to raise the temperature of the cooker to 130oC for fibrous vegetables. This can be achieved by adding weights to the top of the piston. How much weight is to be added to the piston? Approximate the answer to the nearest kg.

Difference in Pressure to be Compensated by weight

98.7 kpa balanced by piston (7500 kg)

Ratio of Pressure Increase

$$= \left(\frac{170.28}{98.7} - 1 \right) \approx 70\%$$

$$\therefore \quad \Delta m = \text{Weight to add}$$

$$= 0.7 \times 7500$$

Additional Weight to be added $\boxed{\simeq 5{,}250 \text{ kg}}$

e. What is the mass of the water in the cooker? Approximate to the nearest kg.

$$m_{H_2O} = \rho_{H_2O} V_{H_2O}$$

$$= \rho_{H_2O} \cdot (A)(H_1)$$

$$= (1000)(0.75)(1)$$

$$\simeq 750 \text{ kg}$$

Mass of Water $\boxed{750 \text{ kg}}$

d. It is required to raise the temperature of the cooker to 130oC for fibrous vegetables. This can be achieved by adding weights to the top of the piston. How much weight is to be added to the piston? Approximate the answer to the nearest kg.

Difference in Pressure to be Compensated by Weight

98.7 kpa balanced by piston (7500 kg)

Ratio of Pressure Increase

$$= \left(\frac{170.28}{98.7} - 1 \right) \approx 70\%$$

$$\therefore \quad \Delta m = \text{Weight to add}$$

$$= 0.7 \times 7500$$

Additional Weight to be added $\boxed{\simeq 5{,}250 \text{ kg}}$

e. What is the mass of the water in the cooker? Approximate to the nearest kg.

$$m_{H_2O} = \rho_{H_2O} V_{H_2O}$$

$$= \rho_{H_2O} \cdot (A)(H_1)$$

$$= (1000)(0.75)(1)$$

$$\simeq 750 \text{ kg}$$

Mass of Water $\boxed{750 \text{ kg}}$