Exam #1
ME/CH EN 2300 Thermo 1

Circle one: I am in ME EN 2300
CH EN 2300

Name Key

Do not plug in any numerical values until they are required to carry the analysis further.

#1 (20 Points) Consider an insulated room that has a uniform temperature, T. At some time, a 100 W light bulb and a 1500 W hair dryer are turned on. How much has the energy content of the room changed one minute after the light and hair dryer have been turned on? State any assumptions.

$$\Delta E = Q_{in,net} + W_{out,net}$$

$$\dot{E} = \dot{Q} + \dot{W} \quad \text{rate form}$$

$$\dot{Q} = 100 \text{ J/sec} + 1500 \text{ J/sec}$$

$$= 1600 \text{ J/sec} \qquad \dot{W} = 0$$

$$\Delta E = Q_{in}, \qquad Q_{in} = \dot{Q}\Delta t \quad (\text{Eq } 2.37)$$

So $\Delta E = \dot{Q}\Delta t$

$$= 1600 \frac{\text{J}}{\text{sec}} \times 60 \text{ sec} =$$

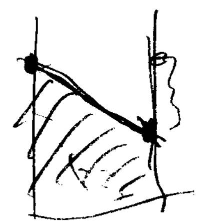
960 kJ

Write 1st law 5

$\dot{Q}$ correct 5

$\Delta E = \dot{Q}\Delta t$ 5

All correct 5



#2 (20 Points) The force required to push in a piston increases with distance as

$$F=Cx^2$$

C is an appropriately dimensioned constant. What is the total work done in moving the piston from $x = 0$ to $x = x_1$? Express your answer in terms of C, x_1, and any other constants or values as appropriate.

$W = F \cdot X$ for constant forces

$W = \int_{x_i}^{x_f} F\,dx$ for variable force

$= \int_0^{x_1} Cx^2\,dx = \frac{Cx^3}{3}\Big|_0^{x_1} = \frac{Cx_1^3}{3}$

W = F × distance 5

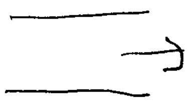
Variable Force $W = \int F\,dx$ 5

Setting up integral correctly 7 (integrand, limits, dx)

All correct 3

#3 (30 points) Water at 25°C flows out of a 10 cm diameter pipe at a velocity of 10 m/sec. If a device is designed to convert all the kinetic energy of the exiting water into work, what is the maximum power output of the device?

$D = 10\,cm \quad V = 10\,m/sec$, Water @ 25°C $\Rightarrow \rho = 997\,Kg/m^3$ App. 3



$W = F \cdot d$

$Power = \text{Work rate} = F \cdot \frac{d}{t} = FV$

~~Kinetic energy~~

$K.E. = \frac{1}{2} m V^2$

$Power = \frac{1}{2} \dot{m} V^2$

$\dot{m} = \rho V A$

So max power $= \frac{1}{2} \rho A V^3$

$A = \pi R^2 = \pi \frac{D^2}{4} = \frac{\pi \cdot .1^2}{4} = .0079$

So max power $= \frac{1}{2}\, 997 \frac{Kg}{m^3} (.0079)\,m^2\, 10^3 \frac{m^3}{sec^3}$ $\quad \frac{Kg\, m}{sec^2} \frac{m}{sec}$

$= 39.38\ KJ/sec$

for moved mass

$KE = \frac{1}{2} m V^2$: 5

$Power = KE/time = \frac{1}{2} \dot{m} V^2$ } 10

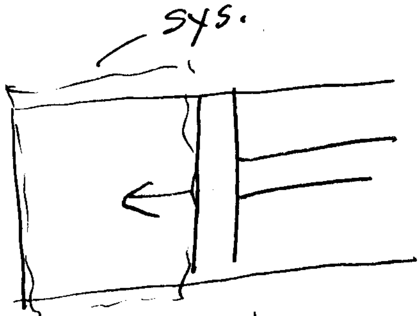
$\dot{m} = \rho A V$: 7

ρ correct : 3

A correct : 3

All correct : 2

#4 (30 points) 1 kg of air in a cylinder is compressed by a piston from 1 m^3 in volume to 0.4 m^3. The initial temperature is 300 K. During the compression, heat is transferred out of the cylinder so that the final temperature is 120 K. how much work is done during this process.



$V_1 = 1\ m^3 \quad T_1 = 300\ K$

$V_2 = .4\ m^3 \quad T_2 = 120\ K$

$W = \int P dV$ 5

Compute P_1 6 (use EOS only 4)
Compute P_2 6
recognize constant P 10 (but must show not assume)
All correct 3

This is boundary work

$$W = \int_{V_1}^{V_2} P dV$$

But we don't Know relationship between P & V.

So lets compute P_1 & P_2 & see what we get:

$P_1 = \frac{mRT}{V_1}$ $\quad m = 1\ Kg$, $R = .287\ \frac{KJ}{Kg\,K}$

$$= \frac{(1\ Kg)\,.287\left(KJ/Kg\,K\right)300\ K}{1\ m^3} = 86.1\ KPa$$

$$P_2 = \frac{1\,(Kg)\left(.287\frac{KJ}{Kg\,K}\right)(120)K}{.4\ m^3} = 86.1$$

So $P_1 = P_2$ & since uniform compression & heating (given in class) this is const pressure process

So $W = P\int_{V_1}^{V_2} dV = P(V_2 - V_1) = 86.1\,KP(-.6\ m^3)$

$= -51.6\,KJ$ on system