Massachusetts Institute of Technology
Department of Aeronautics and Astronautics
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16.003/16.003 Unified Engineering III, IV
Spring 2009

Problem Set 5

Name: ______________________

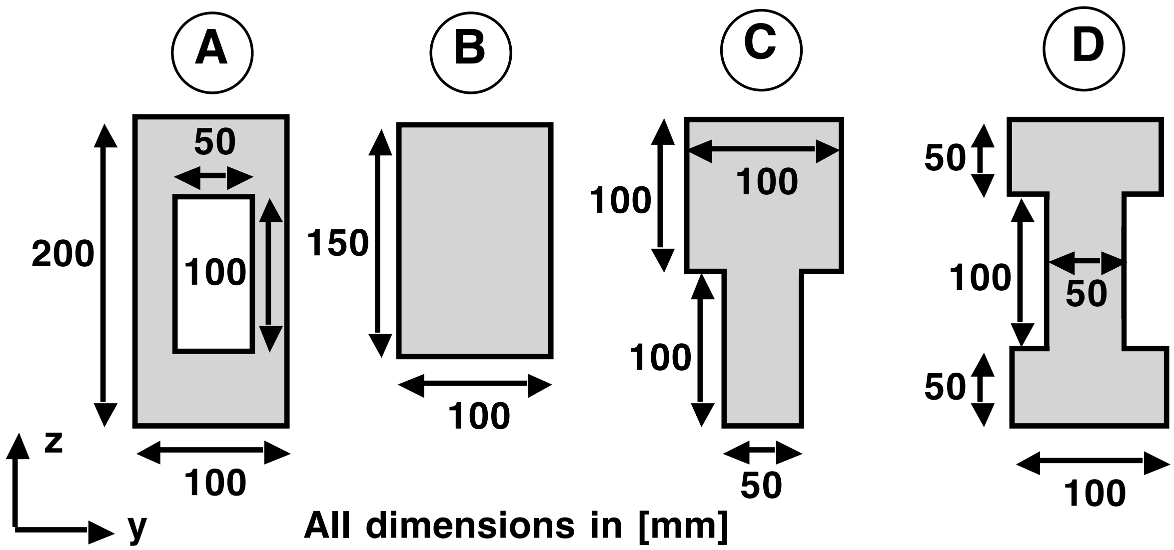
Due Date: 3/13/2009

	Time Spent (min)
M10	
M11	
T10	
T11	
F8	
F9	
F10	
GE Part B	
Study Time	

Announcements:

Unified Engineering Problem Set 5 **Lectures: M11, M12**
Week 6 Spring, 2009 **Units: M4.5**

M10 **(M6.1)** ***(10 points)*** You are asked to evaluate different designs of a 15-meter long statically determinate beam to be made out of steel (E = 200 GPa). Four different cross-sections are under consideration: a rectangular tube, a solid rectangle, a T-beam, and an I-beam. In each case, the cross-sectional area of the beam is the same: 15,000 mm^2. In addition, the overall width is the same in all cases: 100 mm. The dimensions of each of the cross-sections are given in the accompanying figure.



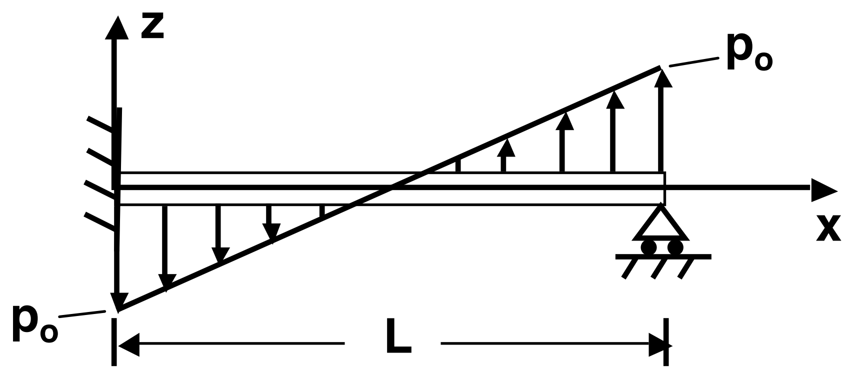
(a) Determine the cross-section that will give the smallest deflection of the beam.

(b) Determine the cross-section that will have the smallest value of the maximum magnitude of the axial stress σ_{xx}, and find the location of the stress in the cross-sectional plane.

(c) Determine the cross-section that will have the smallest value of the maximum magnitude of the shear stress σ_{xz}, and find the location of the stress in the cross-sectional plane.

(d) Comment on the possible beam selections.

M11 (M6.2) ***(10 points)*** The same beam and loading as considered in the problem set for Week 5 (Problem Set 4) is considered here. The beam is of length L and is clamped at one end. The beam has a constant cross-section with area of A and moment of inertia of I, and is made of a material with modulus of E and Poisson's ratio of ν. The beam is loaded by a linearly-increasing load acting downward over the first half of the beam with intensity of p_o at the root of the beam; and acting upward over the last half of the beam with the intensity of p_o at the tip. *The difference with this case is that there is a roller support at the tip.* This configuration is shown in the accompanying figure.



For this case with different support, determine the following and compare such to the results determined for the cantilevered case in the problem set for Week 5 (Problem Set 4):

(a) The maximum deflection of this beam and its location.

(b) The maximum axial stress magnitude, σ_{xx}, and its location in the x-direction.

(c) The maximum shear stress magnitude, σ_{xz}, and its location in the x-direction.

Unified Engineering Spring 2009
Thermodynamics & Propulsion Z. S. Spakovszky

(Add a short summary of the concepts you are using to solve the problem)

Problem T10

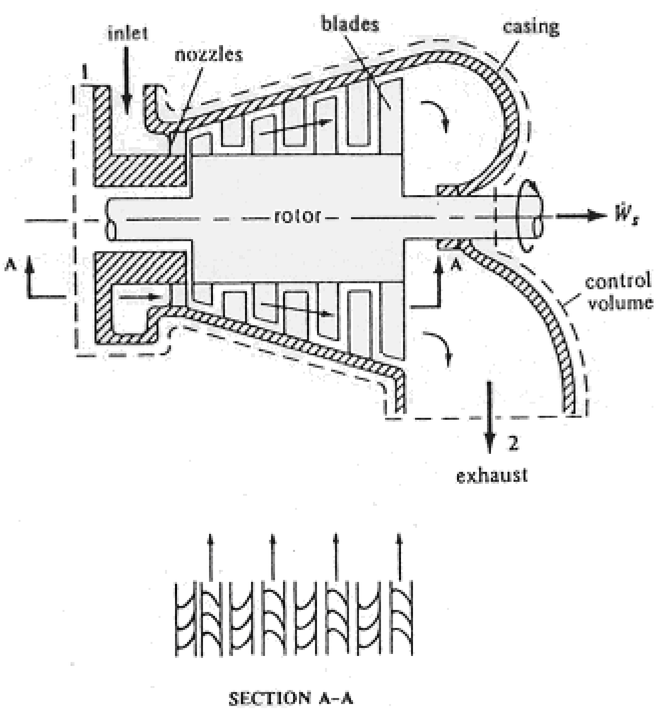
A steam turbine is to provide 1 MW to drive a boiler feed pump. The steam conditions at the turbine inlet are p_1 = 3 MPa and T_1 = 250°C. The turbine exhaust pressure is p_2 = 200 kPa. The adiabatic turbine efficiency is 0.85.

a) Draw the process in a T-s diagram.

b) What steam flow is required?

c) What is the quality of the exit steam?

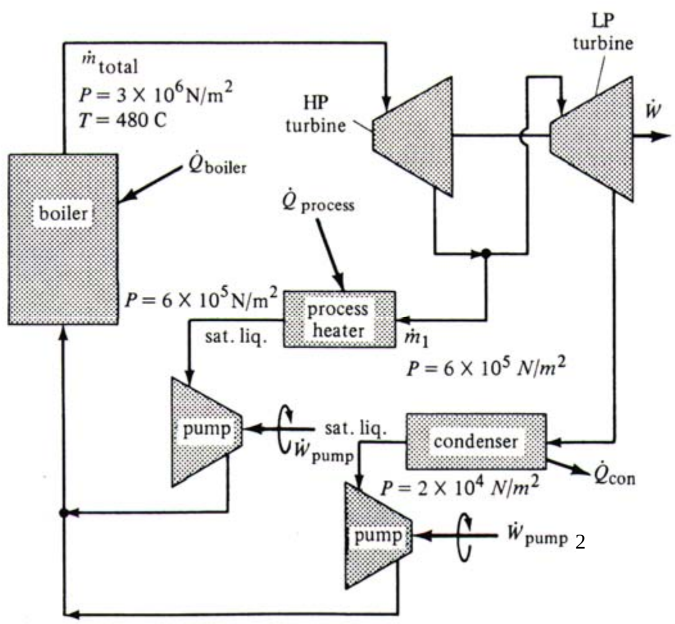
d) What is the entropy generation rate in the turbine?



(Add a short summary of the concepts you are using to solve the problem)

Problem T11

The steam power plant shown below must supply shaft power and 6x10[5] Pa steam for process heating. The power requirement is $\dot{W} = 1000$ kW and the heat transfer requirement for the process heater is $\dot{Q}_{process}$ = -1400 kW (steam flow is cooled). The thermodynamic states are shown in the figure below. The pumps and turbines are modeled as reversible and adiabatic. The heat exchangers are modeled as constant pressure.



a) Introduce station labels and draw the overall cycle in a T-s diagram.

b) Determine the mass flow rate to the process heater $\dot{m}_1$.

c) Determine the mass flow rate at the boiler exit $\dot{m}_{total}$.

d) What is the condenser heat transfer requirement $\dot{Q}_{con}$?

e) What is the thermal efficiency of this system?

You are to design a candidate wing for a sport RC electric aircraft to the following requirements:

density:	$\rho = 1.2\,\mathrm{kg/m^3}$
speed:	$V = 6\,\mathrm{m/s} = 11.1\,\mathrm{mph}$
lift:	$L = 5.0\,\mathrm{N} = 18\,\mathrm{oz}$
span:	$b = 2.0\,\mathrm{m} = 78\,\mathrm{in}$

Assume an elliptic load distribution $\Gamma(y) = \Gamma_0\sqrt{1-(2y/b)^2}$. Assume $dc_\ell/d\alpha = 2\pi$ for the wing airfoils. Assume the wing reference line (e.g. fuselage axis) is aligned with the flight direction, so that $\alpha = 0°$.

Tapered wing: Assume a tapered planform

$$c(y) = c_r + (c_t - c_r)2y/b$$

with taper ratio $c_t/c_r \equiv \lambda = 0.4$.

a) Determine c_r and c_t so that the overall lift coefficient is $C_L = 0.8$.

b) Determine and plot $c_\ell(y)$.

c) Determine and plot $\alpha_{\text{aero}}(y)$.

Three different wings have the following spans and circulation distributions:

i) $b = 10$, $A_1 = 0.03000$, $A_3 = 0$
ii) $b = 11$, $A_1 = 0.02479$, $A_3 = -0.003$
iii) $b = 12$, $A_1 = 0.02083$, $A_3 = -0.006$

All other A_n's are zero. All three wings are operating at the same $V_\infty = 1$ and $\rho = 1$.

a) Determine the lift distribution $L'(y)$ for each wing. Plot both L' versus y on the same graph.

b) Determine the lift L, induced drag D_i, and the span efficiency e for each wing. If all three wings have the same profile drag D_p, which wing appears to be better from the engine's point of view?

c) A wing designer tries to fine-tune the planform via a quintuple-taper wing so that it has a span efficiency of $e = 0.999$ or more. In light of the results from b), is this effort justified?

At maximum available power, an electric motor/propeller combination is measured to have the following thrust versus V:

$$\begin{aligned} T(V) &= k_1 + k_2 V \\ k_1 &= 1.8\,\mathrm{N} \\ k_2 &= -0.02\,\mathrm{N/(m/s)} \end{aligned}$$

An electric aircraft which is to use this powerplant has the following characteristics:

$$\begin{aligned} W &= 8\,\mathrm{N} \\ S &= 0.45\,\mathrm{m}^2 \\ CDA_o &= 0.003\,\mathrm{m}^2 \\ c_d &= 0.018 \\ b &= 1.6\,\mathrm{m} \\ e &= 0.95 \\ c_{\ell_{\max}} &= 1.0 \end{aligned}$$

The aircraft operates at air density $\rho = 1.2\,\mathrm{kg/m^3}$.

a) Determine the minimum sustainable flight speed $V_{\min}$.

b) Determine $D_o(V)$, $D_p(V)$, $D_i(V)$, and the total $D(V)$. Plot all four curves on the same plot, from $V = V_{\min}$ to $V = 20\,\mathrm{m/s}$. Also overlay the $T(V)$ function on this plot.

c) Determine the maximum flight speed $V_{\max}$ of the aircraft. Determine the corresponding flight C_L at this speed.