Massachusetts Institute of Technology
Department of Aeronautics and Astronautics
Cambridge, MA 02139

16.001/16.002 Unified Engineering I, II
Fall 2008

Problem Set 1

Name: ________________________

Due Date: 09/12/2008

	Time Spent (min)
U1	
T1	
T2	
T3	
F1	
Study Time	

Announcements:
Be ready to turn in each problem into a separate bin.

Unified Engineering Fall 2008
Breguet Range Equation Z. S. Spakovszky

Problem U1

a) Discuss the assumptions and approximations that underlie the Breguet range equation. Under what conditions does the Breguet range equation track the actual stage length well? When do the assumptions we made break down such that the range equation becomes less valid?

b) We discussed how far a duck can fly. To estimate the range of a duck, we had to make assumptions about the parameters that govern the duck's flight performance. In particular, there was relatively large uncertainty about the overall efficiency of the duck's propulsion system η_o (the flapping wings). Assuming that a duck loses about 2% of its body weight per hour of migration, estimate the overall efficiency η_o and compare your computed value with the values we assumed in recitation.

c) Assuming steady-level flight and no fuel reserves, estimate the range of a B-747 using the information given in the lecture notes (and/or on Boeing's web page). How well does this compare to the estimates Boeing publishes on their web page?

d) Now assuming that L/D, propulsion system efficiency and final weight are unchanged, estimate the range of a B-747 if the same volume of liquid hydrogen were to be used instead of Jet-A. Discuss your results.

"FUEL"	Heating Value (MJ/kg)	Density (kg/m3)
Jet-A	42.8	800
Liquid Hydrogen	120	70

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

Problem T1

Neon gas at 50°C in a vertical cylinder of diameter 150 mm and 225 mm length has a 6-kg frictionless piston mounted. The molecular mass of neon is 20 g/mol. The outside atmospheric pressure is 98 kPa.

a) What is the pressure inside the cylinder?

b) What is the gas constant *R* for neon?

c) What is the mass of neon inside the cylinder?

d) What is the density of neon?

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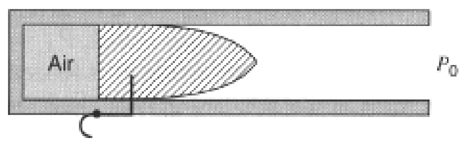
Thermodynamics & Propulsion Z. S. Spakovszky

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

Problem T2

An air pistol contains compressed air in a small cylinder (shown in the figure below). Assume that the volume is 1.6×10^{-5} m^3, pressure is 1.0 MPa, and the temperature is 27 °C when armed. A bullet, m = 0.02 kg, acts as a piston initially held by a pin (trigger); when released, the air expands in an isothermal process (T = constant). Assume R = 287 J/kg-K for air and $p_0 = 10^5$ Pa.



If the air pressure is 0.1 MPa in the cylinder as the bullet leaves the gun, find

a) The barrel volume and the mass of air.
b) The work done by the air and work done on the atmosphere.
c) The work to the bullet and the bullet exit velocity.

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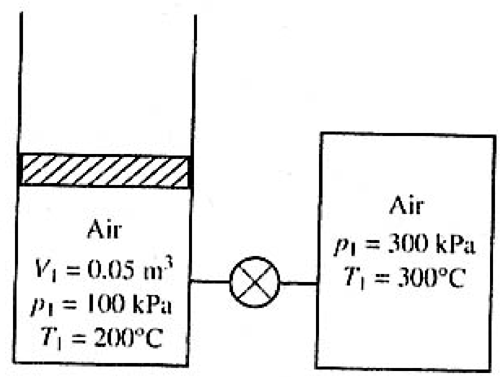
(Add a short summary of the concepts you are using to solve the problem)

Problem T3

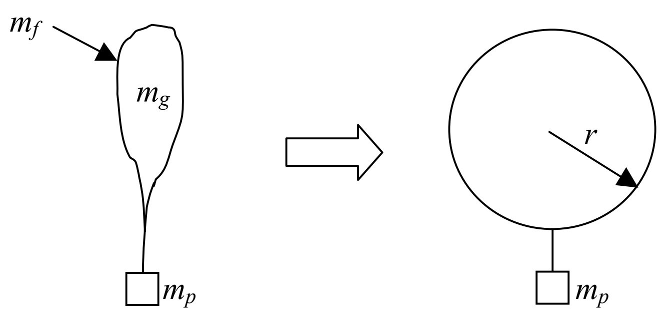
A rigid tank with a volume of 0.1 m^3 is connected to a cylinder fitted with a frictionless piston by a pipe-and-valve arrangement, as shown in the figure. Initially, the valve is shut and the air pressure and temperature in the tank are 300 kPa and 300°C. Initially, the air volume in the cylinder is 0.05 m^3, the pressure is 100 kPa, and the temperature is 200°C. An air pressure of 100 kPa is required to support the weight of the piston and the external ambient pressure. The valve is then opened, and air flows from the tank to the cylinder until the pressure and temperature are uniform throughout the entire system (tank and cylinder) at 100 kPa and 50°C, respectively. Determine the work and heat transfer with the sorroundings.



Unified Engineering **Fall 2008**
Fluids **P. Lozano**

Problem F1

High-altitude balloons are constantly used to probe the upper atmosphere to collect weather data, or even to perform astronomical observations. Consider a balloon that carries a payload mass $m_p = 250$ g. The balloon is partially filled at standard sea-level conditions (p_0 =1 atm, T_0 = 298 °K) with a mass m_g of helium gas (molecular weight 4 g/mol) as shown in the figure. As the balloon climbs, its volume increases until its fabric (of mass $m_f = 1$ kg) becomes a sphere of radius $r = 5$ m.



Answer the following. Explain your answers and procedures.

1) Why does the volume increase?
2) What is the minimum helium mass $m_g^{\min}$ required for neutral buoyancy?
3) Assuming the actual helium mass is $m_g = 1.1 \times m_g^{\min}$, at what altitude h_s will the balloon become spherical?
4) What is the maximum achievable altitude $h_{\max}$?

Assumptions:
- Neglect surface tension of the fabric.
- Once spherical, the balloon volume remains constant.
- Assume the air and helium are at the same temperature at any altitude.
- Use the following model to estimate the air density: $\rho(h) = \rho_0 \exp(-h/h_0)$.
- Take the atmospheric scale height as $h_0 = 8$ km.
- Assume the air and helium behave as ideal gases, *i.e.,* $p = \rho RT$.
- Take the air molecular weight as 29 g/mol.