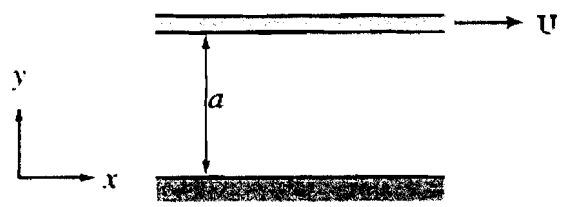
1. (a) Explain physical meanings of Reynolds and Euler numbers. (10%)
   (b) Incompressible viscous fluids steadily flow through a straight horizontal pipe of which the length is l and the diameter is D. The average velocity, density, and viscosity of fluid are V, ρ, and μ, respectively. The pressure drop across the length l is ΔP. Use the dimension analysis method to validate Euler number can be expressed in terms of Reynolds number and dimensionless length. (15%)

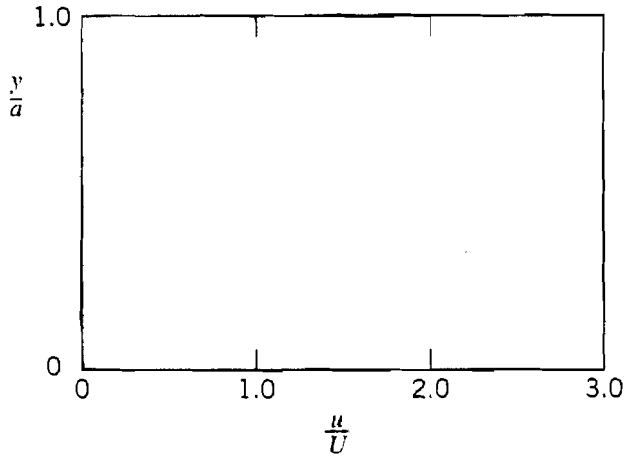
2. In the following figure, incompressible viscous fluids flow steadily through a space between two infinite parallel plates of which the upper plate moves with a constant velocity U. The distribution of velocity of fluid in x direction is expressed as follows.

$$u=\frac{Uy}{a}+\frac{a^2}{2\mu}\left(\frac{\partial p}{\partial x}\right)\left[\left(\frac{y}{a}\right)^2-\left(\frac{y}{a}\right)\right]$$

μ : viscosity
p : pressure

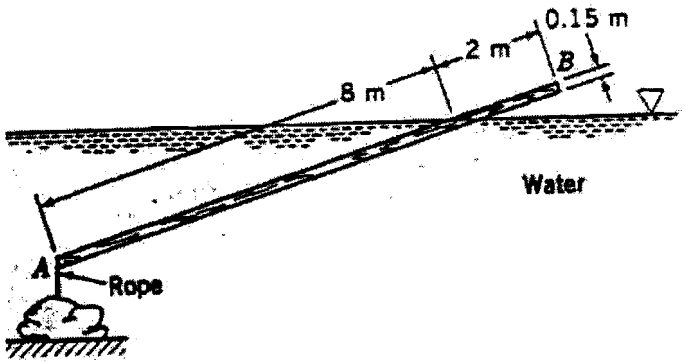
   (a) Calculate the position of the maximum velocity u (7%)
   (b) Calculate the mass flow rate in the space. (8%)
   (c) Plot the velocity profile qualitatively in the following coordinates. (10%)
      (1) without pressure gradient
      (2) the magnitude of pressure gradient is negative.





3. What is viscosity? What is the cause of it in liquids and in gases? How does the dynamic viscosity of liquids and gases vary with temperature? (5 %)

4. The homogeneous timber ***AB*** as shown in the figure below is 0.15 m by 0.35 m in cross section. Determine the specific weight of the timber and the tension in the rope. (10%)



5. Write down the expressions for the physical laws that govern each mode of heat transfer, and identify the variables involved in each relation. (12%)

6. Steam at 250 °C flows in a stainless steel pipe (k=15 W/m • °C) whose inner and outer diameters are 4 cm and 4.6 cm, respectively. The pipe is covered with 3.5-cm-thick glass wool insulation (k=0.038 W/m • °C) whose outer surface has an emissivity of 0.3. Heat is lost to the surrounding air and surfaces at 3 °C by convection and radiation. Taking the heat transfer coefficient inside the pipe to be 80 W/m^2 • °C, determine the rate of heat loss from the steam per unit length of the pipe when air is flowing across the pipe at 4 m/s. (23%)

Assuming a film temperature of T_f = 280 K with the properties of air are k=0.0248 W/m • °C, kinematic viscosity ν =1.44x10^{-5} m^2/s, and Pr=0.716. The correlation of average Nusselt number in a cylinder is expressed as

$$Nu = 0.3+(0.62\,Re^{1/2}\,Pr^{1/3})[1+(Re/282{,}000)^{5/8}]^{4/5}/[1+(0.4/Pr)^{2/3}]^{1/4}.$$