The University of Calgary
Department of Chemical & Petroleum Engineering

ENCH 501: Transport Processes Quiz #1 **September 18, 2007**

Time Allowed: 45 mins. **Name:**

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1. (5 points) Helicopters equipped with "bambi" buckets are used for combating wild fires. As shown in the picture, the collapsible bucket is suspended approximately 10m below the helicopter with cables or ropes. The bucket is dipped into a pond or lake to fill and the water is transported to where the valve at the bottom of the bucket is opened for rapid discharge to douse a flame.

A bambi bucket, capacity 2500 litres, is used to pick up fresh water (ρ = 1000 kg/m^3) from a lake. The empty weight of the bucket is 138 kg. The bucket is suspended by six (6) cables. A colleague suggested to you that any of the four materials below can be used, as long as the diameter of each cable is 2 mm and more.

Is this assumption valid, i.e. can cables made of one or more of the materials fail? Show your steps.

Material	Young's Modulus, GPa	Elastic Strain at failure, ε_{max}
Alloy Steel	210	6.33 (10^{-3})
Kevlar 149, Aramid	186	1.828 (10^{-2})
Nylon fiber	3.9	1.58 (10^{-1})
Hemp	32	9.375 (10^{-3})

2. (5 points) A parachute is under design. A 1/60 scale model is measured to have a drag of 2001.6N when held stationary in water at 20°C (ρ = 998 kg/m^3; μ = 1 mPa.s) flowing at 4.2 m/s in a water tunnel.
Estimate the terminal velocity and the total mass of the prototype (the parachute and the ballast attached) in air (ρ = 1.112 kg/m^3; μ = 17.58 μPa.s). Show all derivations.

Hint: Force of gravity on a mass falling vertically equals the resisting force at a steady speed.

ENCH 501 Quiz #1 Solution Sept. 18, 2007

#1

Assume strings are near vertical.

The force of gravity on the mass should be less than the tensile strength ($E \cdot \varepsilon_{max}$) for the cables. That is

$$\frac{m g'}{A} \leq E \varepsilon_{max}$$ for cables not to fail.

(per unit cross-sectional area)

Also assume equal loads on each cable.

Since $A = \frac{\pi D^2}{4}$; D is diam. of cable

and $m = \frac{\text{Total mass of bucket full of water}}{6}$

$$\frac{4 m g'}{\pi E \varepsilon_{max}} \leq D^2 \quad \text{or} \quad D \geq \sqrt{\frac{4 m g'}{\pi E \cdot \varepsilon_{max}}}$$

The total mass $= \frac{2500}{1000}\ m^3 \cdot 1000\ kg/m^3 + 138 = 2638\ kg$

$\therefore m = \frac{2638}{6} = 439.67\ kg$; $g' = 9.81\ m/s^2$

For each material,	D, mm		
Alloy steel	2.032	> 2mm	∴ will fail (2 mm diam. cable)
Kevlar 149	1.27	< 2mm	∴ safe
Nylon fibre	2.985	> 2mm	∴ will fail
Hemp	4.278	> 2mm	∴ will fail

→

#2 $F = f(L, V, \mu, \rho)$ — 5 variables & 3 dimensions

Drag

∴ 2 dimensionless groups.

$\Pi_1 = L^a V^b \rho^c \mu^d = (L^a)\left(\frac{L}{T}\right)^b \left(\frac{m}{L^3}\right)^c \left(\frac{m}{LT}\right)^d$,

$\Pi_2 = L^{a'} V^{b'} \rho^{c'} F^{d'} = (L^{a'})\left(\frac{L}{T}\right)^{b'} \left(\frac{m}{L^3}\right)^{c'} \left(\frac{ML}{T^2}\right)^{d'}$

Solve to obtain

$$\frac{F}{\rho L^2 V^2} = F\left(\frac{LV\rho}{\mu}\right)$$

← the two dimensionless quantities.

Force coeff. Reynolds #

For kinematic similarity

$$\left(\frac{LV\rho}{\mu}\right)_{model} = \left(\frac{LV\rho}{\mu}\right)_{prototype}$$

$$\frac{L(4.2)(998)}{10^{-3}} = \frac{(60L)(V)(1.112)}{17.58(10^{-6})} \rightarrow V = 1.1 \frac{m}{s}$$

For dynamic similarity

$$\left(\frac{F}{\rho L^2 V^2}\right)_{model} = \left(\frac{F}{\rho L^2 V^2}\right)_{prototype}$$

$$\frac{2001.6}{998(L)^{-2}(4.2)^2} = \frac{F}{1.112(60L)^2(1.1)^2}$$

$$F = 550.73\ N = m\left(9.81\ \frac{m}{s^2}\right)$$

$$\therefore\ m = 56.14\ kg$$

→.