所別：化學工程與材料工程學系碩士班 甲組(一般生)　科目：輸送現象與單元操作　共 2 頁 第 1 頁

本科考試可使用計算器，廠牌、功能不拘　*請在答案卷（卡）內作答

參考用

1. (20%)
Imagine that water is evaporating into initially dry air in the closed vessel. The vessel is isothermal at 25°C; so the water's vapor pressure is 23.8 mmHg. This vessel has 0.8 liter of water with 150 cm^2 of surface area in a total volume of 19.2 liters. After 3 min, the air is 0.05% saturated.
(a) (10%) What is the mass transfer coefficient?
(b) (10%) How long will it take to reach 90% saturation?

2. (10%)
A bubble of oxygen originally 0.1 cm in diameter is injected into excess stirred water. After 7 min, the bubble is 0.054 cm in diameter. What is the mass transfer coefficient if the oxygen concentration at saturation in water is about 1.5×10^{-3} mol/liter at standard conditions.

3. (10%)
A methanol/acetone vapor mixture is being distilled by contact with a methanol/acetone liquid solution. The acetone is transferred from the liquid to the vapor phase and the methanol is transferred in the opposite direction. The condensation of methanol vapor provides the energy for vaporization of acetone. Both components are diffusing through a gas film of 0.1 mm thick. The temperature is around 330K and the pressure is 1.013×10^5 Pa. At these conditions, the pure component enthalpy of vaporization of the methanol and acetone are 1104 and 538.9 kJ/kg, respectively. Develop the flux equation for methanol vapor.

4. (30%)
Liquefied gases are sometimes stored in well-insulated spherical containers vented to the atmosphere. Develop an expression for the steady-state heat transfer rate through the walls of such a container, with the radii of the inner and outer walls being r_0 and r_1 respectively, and the temperatures at the inner and outer walls being T_0 and T_1. The thermal conductivity of the insulation varies linearly with temperature from k_0 at T_0 to k_1 at T_1.

5. (30%)
In a paleontology project, a rare dinosaur skeleton is detected on the bottom of a tar pit near an ancient site. Paleontologists are now striving to recover this precious paleontological treasure. Due to the fragility of the skeleton, the recovery work needs to be conducted with extra care to minimize damage to the dinosaur bones. As an engineer, you are contracted to carry out the challenging task, and plan to build a mockup system to study the flow pattern surrounding and the drag forces exerted on the delicate bones when they are pulled in the tar before actually doing it. You approximate each piece of the real skeleton as a cylinder of 1.5 meter long and 15 cm wide, and use the incompressible Newtonian glycerin (density = 1.261 g/cm^3, viscosity = 1.41 Pa·s at 20 °C) to simulate the tar (kinetic viscosity = 6×10^{-4} m^2/s).

(a) (10%) To determine the condition of your mockup system, you apply the equations of change in the dimensionless form to describing the flow pattern surrounding a bone when it is pulled with the axis parallel to the direction of motion. Please express the **dimensionless** initial and boundary conditions as well as the **dimensionless** equations of change that dictate this flow pattern. If a cylinder of 15 cm long is to be used as a mock bone and to be pulled with the same constant velocity as will be done on a real bone, what diameter shall the mock bone be?

(b) (10%) Following (a), please determine the **dimensionless** velocity profile of the fluid surrounding a bone when it is pulled **steadily**.

注意：背面有試題

所別：化學工程與材料工程學系碩士班 甲組(一般生)　科目：輸送現象與單元操作　共 2 頁 第 2 頁

本科考試可使用計算器，廠牌、功能不拘　*請在答案卷（卡）內作答

(c) (10%) Following (b), please derive the correlation between the drag coefficient and the Reynolds number for a bone under pulling, and determine the drag force experienced by a real bone if it is pulled with a constant velocity of 2 mm/s.

Navier-Stokes Equation

Cartesian coordinate (x, y, z)

$$\rho\left(\frac{\partial v_x}{\partial t}+v_x\frac{\partial v_x}{\partial x}+v_y\frac{\partial v_x}{\partial y}+v_z\frac{\partial v_x}{\partial z}\right)=-\frac{\partial p}{\partial x}+\mu\left[\frac{\partial^2 v_x}{\partial x^2}+\frac{\partial^2 v_x}{\partial y^2}+\frac{\partial^2 v_x}{\partial z^2}\right]+\rho g_x$$

$$\rho\left(\frac{\partial v_y}{\partial t}+v_x\frac{\partial v_y}{\partial x}+v_y\frac{\partial v_y}{\partial y}+v_z\frac{\partial v_y}{\partial z}\right)=-\frac{\partial p}{\partial y}+\mu\left[\frac{\partial^2 v_y}{\partial x^2}+\frac{\partial^2 v_y}{\partial y^2}+\frac{\partial^2 v_y}{\partial z^2}\right]+\rho g_y$$

$$\rho\left(\frac{\partial v_z}{\partial t}+v_x\frac{\partial v_z}{\partial x}+v_y\frac{\partial v_z}{\partial y}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu\left[\frac{\partial^2 v_z}{\partial x^2}+\frac{\partial^2 v_z}{\partial y^2}+\frac{\partial^2 v_z}{\partial z^2}\right]+\rho g_z$$

Cylindrical coordinate (r, θ, z)

$$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}+v_z\frac{\partial v_r}{\partial z}-\frac{v_\theta^2}{r}\right)=-\frac{\partial p}{\partial r}+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_r)\right)+\frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2}+\frac{\partial^2 v_r}{\partial z^2}-\frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}\right]+\rho g_r$$

$$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+v_z\frac{\partial v_\theta}{\partial z}+\frac{v_r v_\theta}{r}\right)=-\frac{1}{r}\frac{\partial p}{\partial \theta}+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_\theta)\right)+\frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2}+\frac{\partial^2 v_\theta}{\partial z^2}+\frac{2}{r^2}\frac{\partial v_r}{\partial \theta}\right]+\rho g_\theta$$

$$\rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2}+\frac{\partial^2 v_z}{\partial z^2}\right]+\rho g_z$$

Newton's law of viscosity

$$\tau_{rr}=-\mu\left[2\frac{\partial v_r}{\partial r}\right]+\left(\frac{2}{3}\mu-\kappa\right)(\nabla\cdot\bar{v})$$

$$\tau_{\theta\theta}=-\mu\left[2\left(\frac{1}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_r}{r}\right)\right]+\left(\frac{2}{3}\mu-\kappa\right)(\nabla\cdot\bar{v})$$

$$\tau_{zz}=-\mu\left[2\frac{\partial v_z}{\partial z}\right]+\left(\frac{2}{3}\mu-\kappa\right)(\nabla\cdot\bar{v})$$

$$\tau_{r\theta}=\tau_{\theta r}=-\mu\left[r\frac{\partial}{\partial r}\left(\frac{v_\theta}{r}\right)+\frac{1}{r}\frac{\partial v_r}{\partial \theta}\right]$$

$$\tau_{\theta z}=\tau_{z\theta}=-\mu\left[\frac{1}{r}\frac{\partial v_z}{\partial \theta}+\frac{\partial v_\theta}{\partial z}\right]$$

$$\tau_{zr}=\tau_{rz}=-\mu\left[\frac{\partial v_r}{\partial z}+\frac{\partial v_z}{\partial r}\right]$$

$$(\nabla\cdot\bar{v})=\frac{1}{r}\frac{\partial}{\partial r}(rv_r)+\frac{1}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{\partial v_z}{\partial z}$$