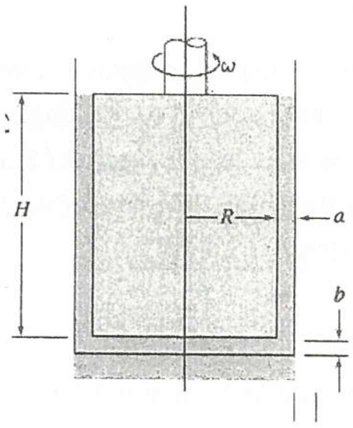
Problem 1:

Viscometer is important in fluid mechanics, as it can measure one of the most critical liquid properties – viscosity. A commonly-seen concentric-cylinder viscometer is shown. Viscous torque is produced by the annular gap around the inner cylinder. Additional Viscous torque is produced by the flat bottom of the inner cylinder as it rotates above the flat bottom of the stationary outer cylinder.



(a) What are the SI units for dynamic viscosity and kinematic viscosity? Is "poise (p)" dynamic viscosity or kinematic viscosity? (3%)

(b) Obtain an algebraic expression for the viscous torque due to flow in the annular gap of width, a. (4%)

(c) Obtain an algebraic expression for the viscous torque due to flow in the bottom clearance gap of height, b. (4%)

(d) Prepare a conceptual plot showing the ratio, b/a, required to hold the bottom torque to 1.2 percent or less of the annulus torque, versus the other geometric variables. (4%)

(e) If a=1mm, b=2mm, and R=10mm, what is the minimal value for H? In other words, how much liquid is required to hold the bottom torque to 1.2 percent or less of the annulus torque? (3%)

Problem 2:

The Grashof number (Gr) arises in the study of natural convection heat flow. If the number is given as: $\frac{D^3\rho^2\beta g\Delta T}{\mu^2}$

(a) What is the physical meaning of the Grashof number? (5%)

(b) What is the physical meaning of b and its dimension? (6%)

Problem 3:

A loaf of bread having a surface temperature 353 K is being baked in an oven whose walls and their air are at 487 K. The bread moves continuously through the large oven on an open chain belt conveyor. The emissivity of the bread is estimated as 0.86 and the loaf can be assumed a rectangular solid 120 mm high x 120 mm wide x 350 long. Calculate the radiation heat-transfer rate to the bread, assuming that it is small compared to the oven and neglecting natural convection heat transfer. (Boltzmann's constant= $5.67\text{x}10^{-8}$) (15%)

Problem 4:

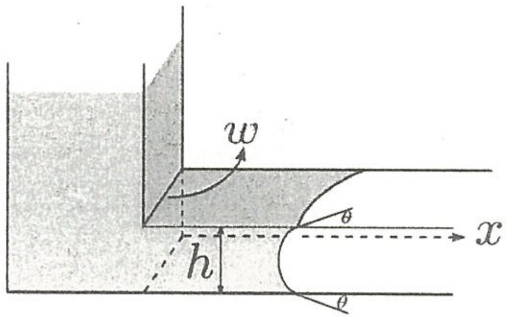
Capillary pump utilizes the capillary force as the dominant force to drive liquid transport at the micro- and nanoscale. We apply a capillary pump on a horizontal, microfluidic channel with flat rectangular cross-sections of width w and height $h \ll w$. The pressure drop Δp between the entrance at x=0 and the advancing meniscus at x=$L(t)$ is constant and the surface tension and viscosity of the fluid are γ and η, respectively.

Please calculate

(a) the pressure drop across the meniscus (5%),

(b) the volumetric flow rate by applying Hagen-Poiseuille equation (5%),

(c) the average velocity of the fluid and the time-dependent advancing distance L (15%).



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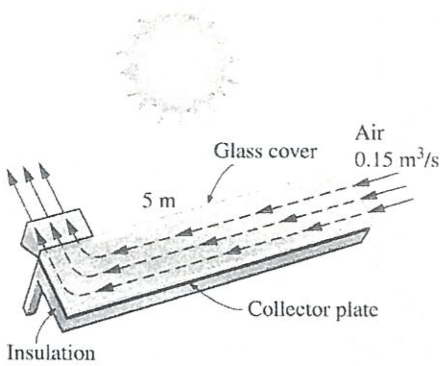
Problem 5:

The cardiac output in a human is about 6 L min^{-1}. Blood enters the right side of the heart at a pressure of about 0 mmHg gauge and flows via the pulmonary arteries to the lungs at a mean pressure of 11 mmHg gauge. Blood returns to the left side of the heart through the pulmonary veins at a mean pressure of 8 mmHg gauge. The blood is then ejected from the heart through the aorta at a mean pressure of 90 mmHg gauge. Estimate of the total work performed by the heart. Carefully state any assumptions and express your answer in watts. (10%)

Problem 6:

Consider an air solar collector that is 1.5 m wide and 5 m long and has a constant spacing of 4 cm between the glass cover and the collector plate. Air flow at an average temperature of 42 °C at a rate of 0.15 m^3/s through the 1.5-m wide edge of the collector along the 5-m long passage-way.



Assume the properties of air at 1 atm and 42° are $\rho = 1.109$ kg/m^3, $\mu = 1.941\times10^{-5}$ kg/m·s.

Colebrook equation for turbulent flow is $\frac{1}{f} = -2.0 \log_{10}\left(\frac{\epsilon / D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$

Disregarding the entrance and roughness effects and the 90° bend,

(a) Calculate the hydraulic diameter of the collector. (5%)

(b) Calculate the Reynolds number of the flow and the corresponding friction factor. (6%)

(c) Determine the pressure drop in the collector. (10%)

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