GJ

The University of Calgary
Department of Chemical & Petroleum Engineering

ENCH 501: Transport Processes Quiz #7 **December 6, 2005**

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

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1. (4pts) Satellites are used to observe large scale events on land and the seas. The development of weather patterns, hurricanes and spread of large oil spills are some of the events monitored.

An oil tanker spills a substantial amount of crude oil on calm seas. It is assumed that ocean currents and the wind do not aid the spreading of the oil. Also, the properties of the oil are not changing due to evaporation of volatile components, dissolution of parts of the oil in water or aging due to reactions on radiation from the sun. At a stage after the spill, the following data was obtained from the satellite:

Time, hours/minutes	3/6	4/12
Radius, km	2.6723	2.8831

Determine the regime of the spreading at this time and the forces acting on the oil slick.

2. (6pts) Heat generated from many electronic devices are often dissipated by the use of fins or extended surfaces. The fins, plates or rods, are usually attached to the body within which the heat is being generated. Convection currents around the body and the fins carry off the heat.

An electronic component is a 1 cm cube producing 0.8W heat. The body is in air at 18°C, its surface is to be maintained at a constant temperature of 45°C and the heat transfer coefficient in the space is given as 26 W/m^2K. It is recommended that aluminum fins be attached to help in heat dissipation. The fins are cylindrical rods, 2mm diameter and 8mm long. The open end of each fin is covered by a small felt pad, i.e. insulated.

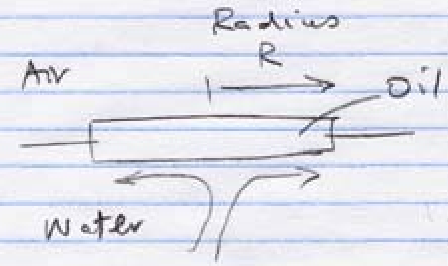
How many fins are required to be attached to the body? Show all important calculations.

Data: Properties of Aluminum

$\rho = 2707\ kg/m^3$; $k = 204\ W/mK$; $C_p = 0.896\ kJ/kgK$

ENCH 501 Quiz # 7 Solution Dec. 6, 2005

Problem # 1



There are 3 distinct regimes –

short times – forces are $\uparrow$ gravity + $\downarrow$ Inertia

Intermediate – $\uparrow$ gravity + $\downarrow$ Viscous

Long times – $\uparrow$ surface tension and $\downarrow$ Viscous.

By order-of-magnitude analysis

short time, $R \sim [g \Delta V]^{1/4} t^{1/2}$ (Notes)

Intermediate $R \sim (g\Delta)^{1/6} V^{1/3} \nu^{-1/12} t^{1/4}$

Long time $R \sim \sigma^{1/2} [\rho \mu]^{-1/4} t^{3/4}$

Plots of $\ln R$ vs $\ln t$ gives a slope and allows determination of regime.

In general $\ln R = n \ln t + C_0$

Given (t_1, R_1) and (t_2, R_2)

$$\ln R_2 - \ln R_1 = n (\ln t_2 - \ln t_1)$$

or $$\ln (R_2/R_1) = n \ln (t_2/t_1)$$

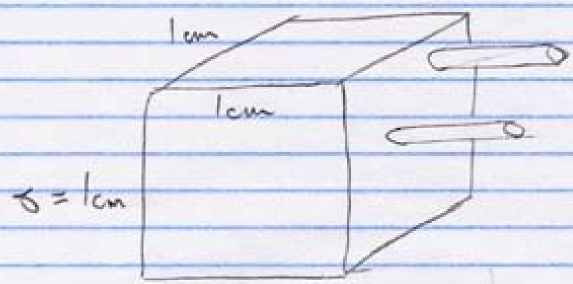
substitute values

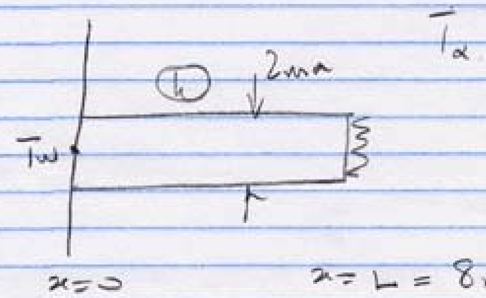
$$\ln \left(\frac{2.8831}{2.6723} \right) = n \ln \left(\frac{4.2}{3.1} \right)$$

$$n = \frac{0.07592}{0.30368} = 0.25$$

The spread is in the intermediate regime and the forces are gravity (spreading) and viscous (retarding).

Problem #2





Energy Balance:

The heat loss from the body = Heat produced and fins

Area of base of each fin = πR^2

If there are n fins, the area of body not covered by fins = $6(\delta^2) - n(\pi R^2)$

Heat loss per fin can be estimated from

$$Q = -kA \left.\frac{dT}{dx}\right|_{x=0} = \int_0^L h(T - T_\alpha) 2\pi R\, dx$$

For the system given, with the tip (x = L) insulated, the temperature profile is: (P = perimeter; A = x-section)

$$\frac{T - T_\alpha}{T_w - T_\alpha} = \cosh Nx - \tanh(NL)\sinh Nx \; ; \quad N^2 = \frac{hP}{kA}$$

$$Q = -kA \left.\frac{dT}{dx}\right|_{x=0} = \sqrt{hPkA}\,(T_w - T_\alpha)\tanh NL$$

where $P = 2\pi R$, $A = \pi R^2$, $R = 1\text{mm}$ or 10^{-3} m, $k = 204$ W/mK, $L = 8(10^{-3})$ m, $h = 26$ W/m²K

substitute $Q = 0.01023\,(27)\tanh(15.9656 \times 0.008)$

$= 0.0351$ W

Energy Balance on body + fins

$$hA(T - T_\infty) + nQ = 0.8 \text{ W}$$

$$26\left(6(0.01)^2 - n(\pi)(10^{-6})\right)(45-18) + n(0.0351) = 0.8$$

$$0.4212 - n(0.002205) + n(0.0351) = 0.8$$

$$n = 11.52$$

Since there are no fractional fins, use 12 →

Note:

$$\frac{\text{Area covered by fins}}{\text{Total cube area}} = \frac{12(\pi)(10^{-6})}{6(0.01)^2} = 0.0628$$

or approx $\frac{1}{16}$th of the area.

Heat transfer by Fins $= 12(0.0351)$
$= 0.4212$

This is $\frac{0.4212}{0.8} = 0.5265$, or

almost 53% of the heat dissipated.