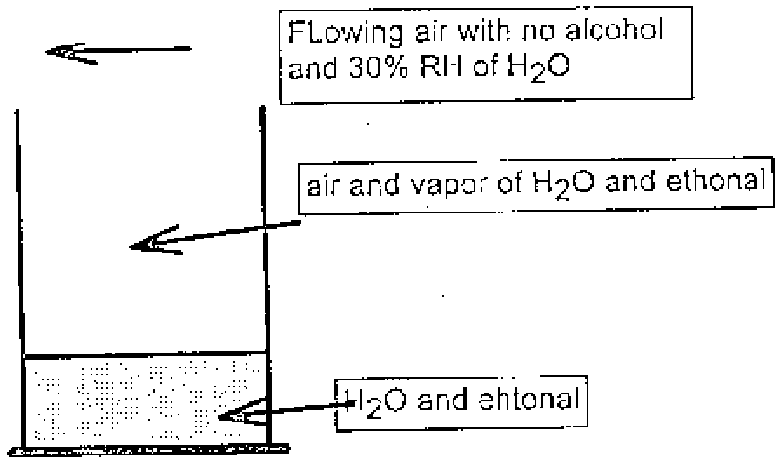
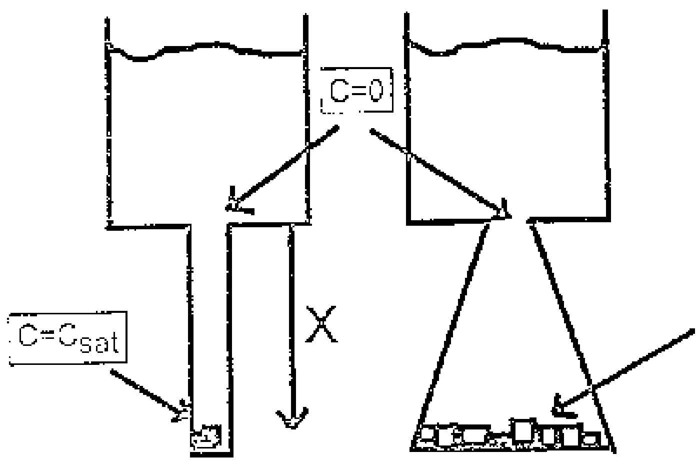
1. (20%) A glass is filled half way with a mixture of water and ethanol. It is then placed on a table where the ventilation is good. The room air flowing above the glass is assumed to contain no alcohol and a relative humidity of 30%. Air (Nitrogen and oxygen) does not dissolve into the mixture. How will you set up a model to describe the evaporation rate of the contains in glass? Give the fundamental equations you will use. Write down the assumptions that you have made. Substitute the given conditions in the problem into the equations. Be sure to define the symbols you used.



2. (15%) The "Fick's law" for diffusion was established by A.E. Fick back in 1855. The famous experiment he put forward was as described below;
A cylinder and a funnel were connected to the bottom of two large reservoirs respectively. Both were filled with water. Sodium chloride salts were placed in the bottom of the cylinder and the funnel. By periodically replacing the water in the reservoirs, he was able to kept the salt concentration in the reservoirs practically zero. He then measures the density distribution along the high of the cylinder and funnel. It is know that the density is proportional to the salt concentration.
Now, 140 years later, can you predict what kind of density distribution should he find? Can you give an account of the result based on the "Fick's Law"?



(20%)

3. The temperature distribution across a plane wall of 0.3 m thick at a certain instant of time is

$$T(x) = A + Bx - Cx^2$$

where T is in degrees Celsius and x is in meters, A = 200°C, B= -200°C/m, and C= 30°C/m². The wall has a thermal conductivity of 1 W/m K.

(a) On a unit surface area basis, determine the rate of heat transfer into and out of the wall.

(b) Estimate the rate of change of energy stored by the wall.

(c)If the cold surface is exposed to a fluid at 100°C, what is the convection coefficient?

(15%)

4. Consider a very long, concentric pipe heat exchanger having hot and cold water inlet temperatures of 85 and 15°C. The flow rate of the hot water is twice that of the cold water. Assuming equivalent hot and cold water specific heats, determine the hot water outlet temperature for the following modes of operation: (a) counterflow, (b) parallel flow.

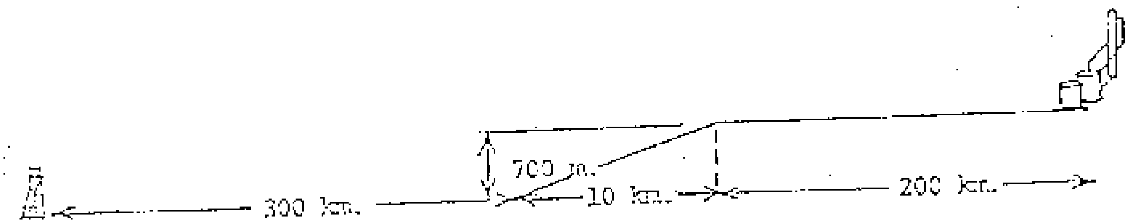
(30%)

5. A pipeline company is going to construct an 18" pipeline to transport 120,000 barrels per day of crude oil from a newly discovered oil field to an established refinery. The proposed route covers 510 kilometers, with one 10 kilometer segment having a 700 meter rise in elevation, as shown in the diagram below. The pipeline will operate continuously, i.e. with negligible down time. As part of the preliminary cost evaluation, your assignment is to determine the number of centrifugal pumping stations which are required to maintain the specified flow rate. The data for the characteristic curve of the pumping station is listed below.

q (gal/min)	1000	2000	3000	4000	5000
ΔH (m^2/s^2)	1080	1055	1025	975	910

The properties for the crude oil are: viscosity 4 cp
specific gravity 0.80

The properties of the pipe are: ID = 18 inches
$f = 0.0326\ Re^{-0.16}$ if $Re > 10^5$



(a) How many stations are required for the 500 km horizontal segment? (The stations are evenly spaced.)

(b) How many stations are required for the 10 km segment with the gradient? (Again, the stations are evenly spaced.)

(c) Explain qualitatively, what would happen, instead of spacing them evenly, all pumps were located at one super station. Wouldn't this arrangement be better.

Useful conversion factors:

- 1 barrel = 42 gal
- 1 gal = 0.1337 ft³
- 1 m = 3.2808 ft
- 1 cp = 0.001 kg/m s