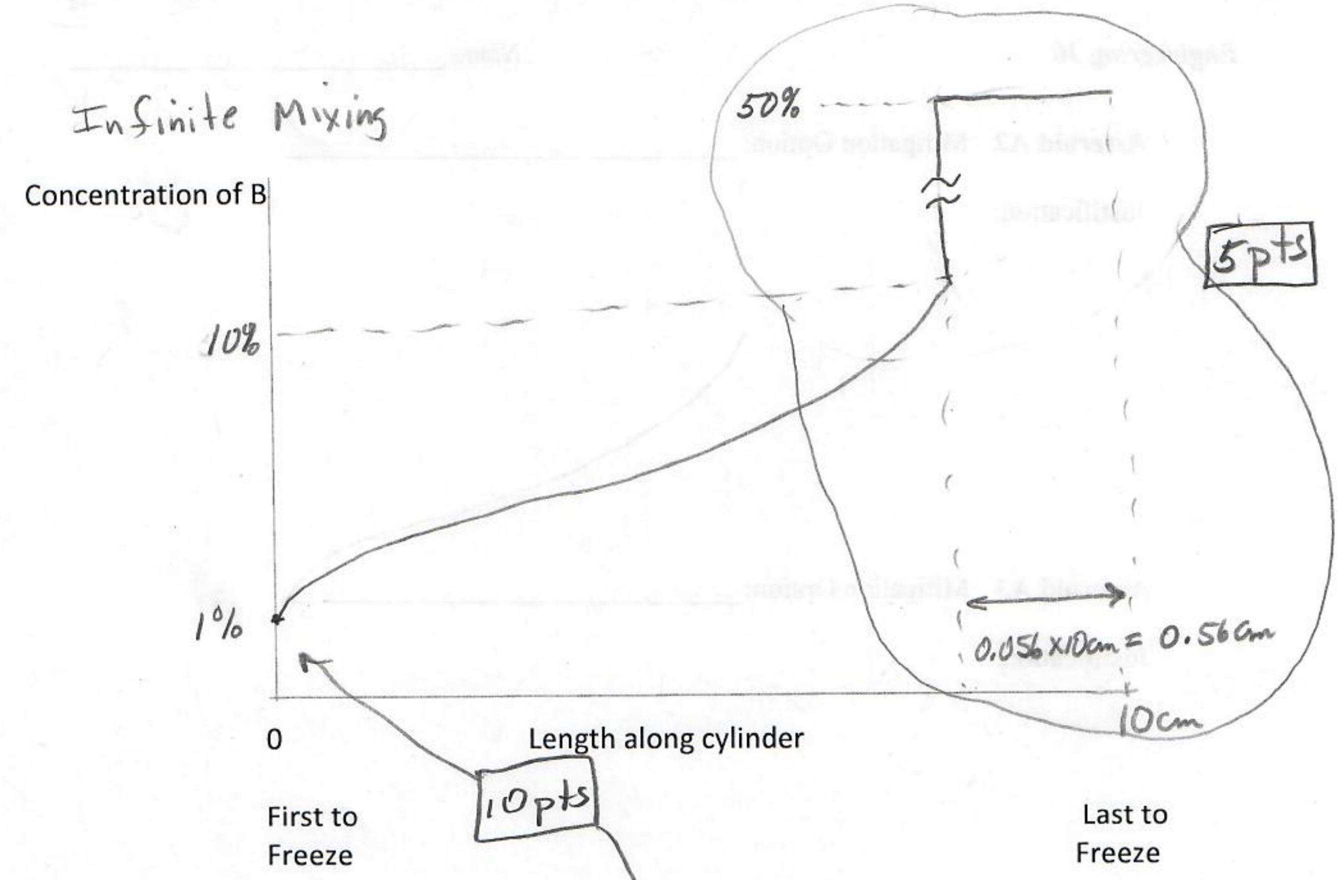
(20)

Infinite Mixing



$$C_s^* = k C_o (1 - f_s)^{k-1} \qquad k = \frac{10}{50} = 0.2$$

First solid to Form $\quad C_s^* = (0.2)(5)(1-0)^{0.2-1} = 1\%B$

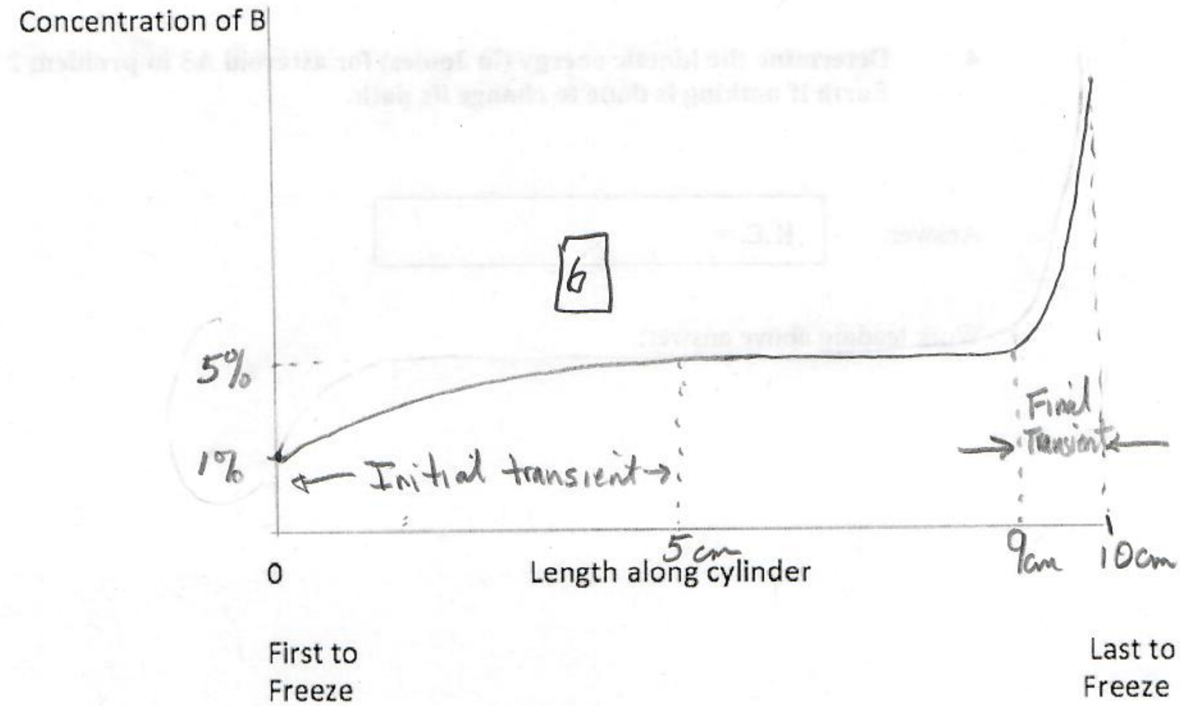
$$10\% = (0.2)(5)\, f_E^{0.2-1}$$

$$10 = f_E^{-0.8}$$

$$\therefore f_E = 10^{-1.25} = 0.056$$

5pts

(20)



7 length of initial Transient $= \frac{D_L}{kR} = \frac{1\times10^{-5}\,cm^2/s}{(0.2)(0.1\times10^{-4}\,cm/s)} = 5\,cm$

7 length of final transient $= \frac{D_L}{R} = \frac{1\times10^{-5}\,cm^2/s}{0.1\times10^{-4}\,cm/s} = 1\,cm$

(b) For the ingot that solidified with infinite mixing in the liquid:

(i) What fraction of the ingot has a concentration of B that is greater than 5%?

f_β in Eutectic $= \frac{90-50}{90-10} = 0.50$

(5) $f_E = 0.056$

f of β in the ingot $= (0.50)(0.056) = 0.028$

(ii) After solidification is complete what is the amount of β-phase in the ingot?

$5\% = (0.2)(5\%)\, f_L^{-0.8}$

$5 = f_L^{-0.8}$

(10) $f_L = 5^{-1.25} = 0.1337$

(c) A third ingot of the same dimensions and composition is frozen at the rate of 10 micron/s and with a thermal gradient in the liquid phase at the liquid-solid interface of 100°C/cm. Will solidification occur with a plane front or will the Liquid-Solid interface break down resulting in cellular or dendritic solidification? Explain your answer.

Criterion for PFS :

~~20~~ 15

$$\frac{G_L}{R} \geq \frac{m_L C_s^*(1-k)}{k D_L}$$

5

$$m_L = \frac{1000°C - 500°C}{0 - 50\%} = -10\ °C/\%$$

At steady state $C_s^* = C_o$

$$\frac{G_L}{R} \geq \frac{m_L C_o (1-k)}{k D_L} = \frac{(-10°C/\%)(5\%)}{1\times10^{-5} cm^2/s}\left(\frac{1-0.2}{0.2}\right)$$

$$= \frac{200°C \cdot s/cm^2}{1\times10^{-5}}$$

For $R = 10 \mu m/s$

8 ~~10~~

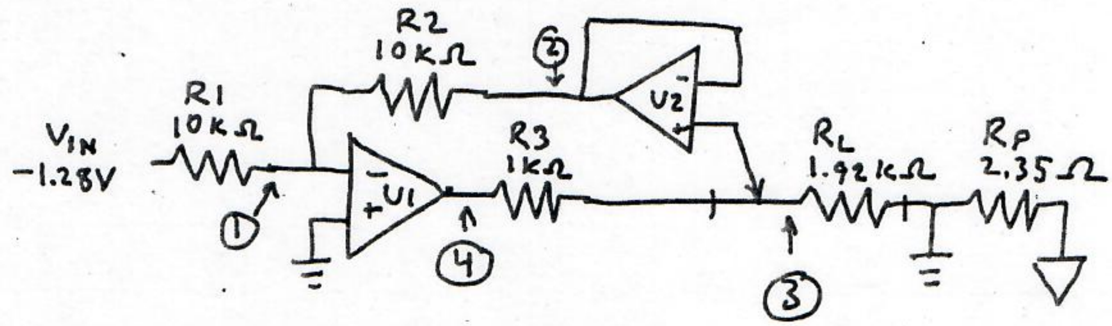
$$G_L \geq 2\times10^4\ °C/cm$$

Actual Gradient is 100°C

~~5~~ ~~10~~ 2

$\Rightarrow$ Plane front will breakdown resulting in cellular or dendritic solidification

2. Consider the following circuit.



1. Determine the current at each of the four circled locations.
2. Determine the voltage at each of the four circled locations.

Please state any assumptions that you make.

Summary: (3pts. each)

	I	V
(1)	1.28×10^{-4} A	0
(2)	1.28×10^{-4} A	+1.28V
(3)	6.7×10^{-4} A	+1.28V
(4)	6.7×10^{-4} A	+1.95V

(3pts) (1) Current into inputs of Op amp = 0

(3pts.) (2) With negative feedback $V^+ = V^-$

(1) V^- at (1) is $= V^+ = 0$

$\Rightarrow I$ at (1) $= \frac{1.28V}{10k\Omega} = 1.28\times10^{-4}A$

(2) I through R2 $= 1.28\times10^{-4}A$ $\Rightarrow$ V at (2) $= (1.28\times10^{-4}A)10k\Omega = +1.28V$

= I at (2)

(3) V at (3) is = V at (2) = + 1.28V

I through $R_L = \frac{1.28V}{1.92k\Omega} = 6.7\times10^{-4}A$

(4) I at (3) must come from I at (4)

$\therefore$ V across $R_3 = (6.7\times10^{-4}A)(1k\Omega) = 0.67V$

$\therefore$ V at (4) $= 0.67V + 1.28V = 1.95V$

(1.28V = V at (3))