Prelab Assignment 1

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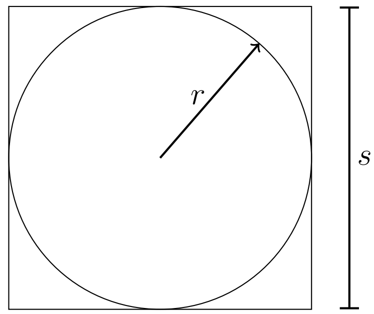
Problem 1

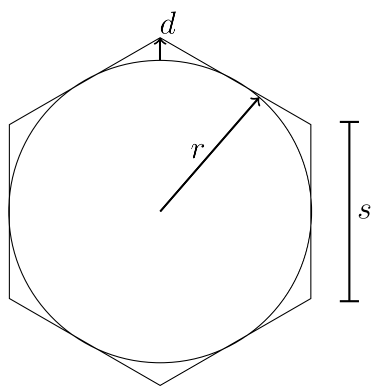
The square RVE for the fiber is shown.



Assuming the length into the page is h, then the fiber volume fraction is given by:

$$\begin{aligned} v_f &= \frac{\pi r^2 \cancel{h}}{s^2 \cancel{h}} \\ &= \frac{\pi r^2}{4r^2} \qquad [s = 2r] \\ &= \frac{\pi}{4} \end{aligned}$$

The hexagonal RVE for the fiber is shown.



Again, assuming the length into the page is h, and knowing the fact that each angle in the hexagon is 120, and using the figure above, then:

$$\begin{aligned} \cos(60^\circ) &= \frac{s/2}{r+d} \\ \cos(30^\circ) &= \frac{r}{r+d} \\ d &= \left(\frac{2}{\sqrt{3}} - 1\right) r = s - r \\ \rightarrow s &= \frac{2}{\sqrt{3}} r \end{aligned}$$

Then after some algebra,

$$
\begin{aligned}
v_f &= \frac{\pi r^2 \cancel{h}}{\frac{3\sqrt{3}}{2} s^2 \cancel{h}} \\
&= \frac{\pi r^2}{\frac{3\sqrt{3}}{2}\frac{4}{3} r^2} \\
&= \frac{\pi}{2\sqrt{3}}
\end{aligned}
$$

Problem 2

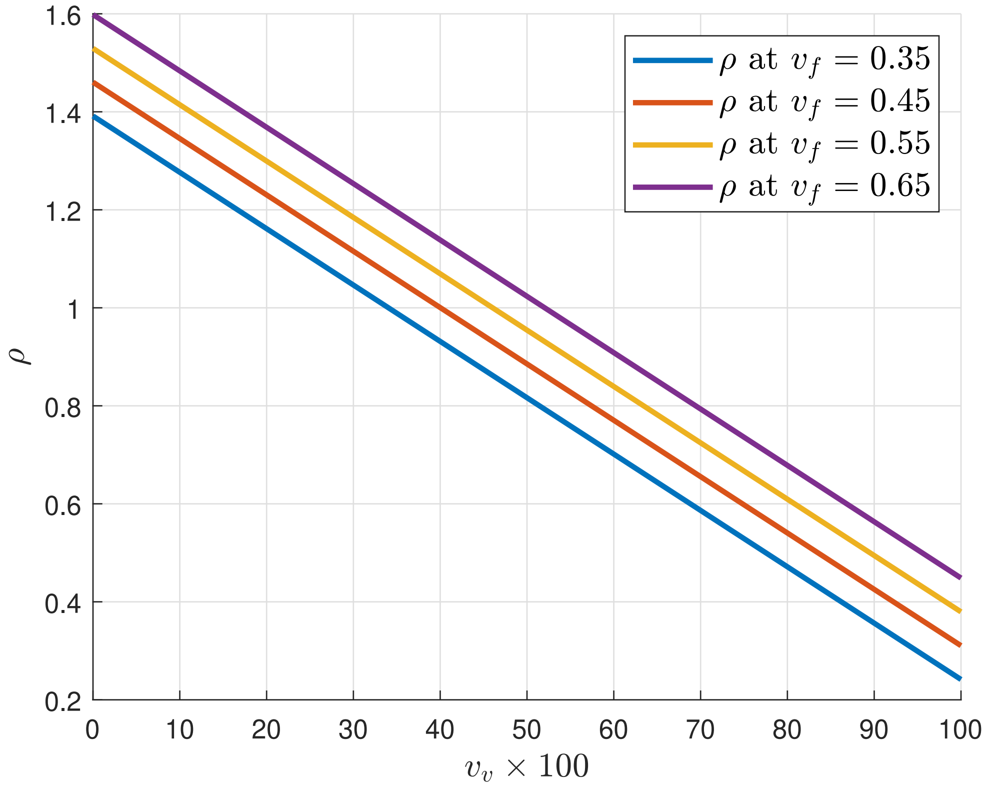


Figure 1: **Composite density vs void content with varying fiber volume fraction**

(a) Using the following equations:

$$
\begin{aligned}
\rho &= \rho_f v_f + \rho_m v_m \\
1 &= v_f + v_m + v_v
\end{aligned} \tag{1}
$$

Then solving for v_m from the second equation, and substituting into the first one, we obtain the relation:

$$
\begin{aligned}
\rho &= \rho_f v_f + \rho_m \left(1 - v_f - v_v\right) \\
&= \rho_f v_f + \rho_m - \rho_m v_f - \rho_m v_v \\
v_v &= \frac{\left(\rho_f - \rho_m\right) v_f + \left(\rho_m - \rho\right)}{\rho_m}
\end{aligned} \tag{2}
$$

Substituting $\rho_f = 1.84\ g/cm^3$, $\rho_m = 1.15\ g/cm^3$, $\rho = 1.3766\ g/cm^3$, $v_f = 0.55$, where ρ was obtained from calculating the initial composite density and multiplying it by 90%, we obtain $v_v = 0.1330$. This is not acceptable, as an acceptable limit for void volume fraction is 3-5% depending on the application.

(b) Complete the chart below using DA 409U/G35 150 prepreg data.

Table 1: **DA 409U/G35 150 prepreg data**

Density (g/cm^3)	**Fiber fraction** (v_f)	**Void fraction** (v_v)
1.600	0.70	0.03
1.550	0.66	0.05
1.564	0.65	0.03
1.700	0.83	0.02
1.625	0.75	0.04

Problem 3

(a) Zero void percent

Relevant equations:

$$\begin{aligned} v_m &= 1 - v_f \\ \rho &= \rho_f v_f + \rho_m (1 - v_f) \end{aligned} \tag{3}$$

Setting up a system of equations. Let boron be the matrix, and epoxy be the fiber.

$$1.626 = 0.66\rho_f + 0.34\rho_m \tag{4}$$

$$1.687 = 0.73\rho_f + 0.27\rho_m \tag{5}$$

Solving yields $\rho_f = 1.9223$, $\rho_m = 1.0509$.

(b) 5% void percent

Relevant equations:

$$\begin{aligned} v_m &= 1 - v_f - v_v \\ \rho &= \rho_f v_f + \rho_m (1 - v_v - v_f) \end{aligned} \tag{6}$$

Again letting boron be the matrix, and epoxy be the fiber.

$$1.626 = 0.66\rho_f + 0.29\rho_m \tag{7}$$

$$1.687 = 0.73\rho_f + 0.22\rho_m \tag{8}$$

Solving yields $\rho_f = 1.9776$, $\rho_m = 1.1062$.

Problem 4

Cured volume is $9.5 \times 1.6 \times 0.053 = 0.8056\ in^3$. Given the shrinkage is 7%, then $V_c - 0.07V_c = 0.8056\ in^3$, then $V_c = 0.8662\ in^3 = 10 \times 1.5 \times t$. Therefore, $t = \frac{0.8662}{10 \times 1.5} = 0.0577\ in$