We wish to use fiber-reinforced composites to design a recreational downhill ski, and as a preliminary step we assume the weight of a 150-lb (668 N) skier is distributed uniformly over the snow by a ski 180 cm in length and 7.5 cm in width as shown in Fig. 4.36. This distribution is highly approximate, but suitable for getting the design started. The bending moment at the midpoint is then half the total skier weight times one-quarter of the ski length. Dividing by the ski width to obtain moment per unit width, we have

\[ M_s = \frac{(668/2)(1.8/4)}{0.075} = 2090 \text{ N} \]

We will carry out an initial analysis considering only this bending moment, although in reality the shear resultant due to the transverse loading can be expected to produce stresses on the same order as the bending. As a preliminary design choice, we try layers of glass/epoxy on the top and bottom surfaces, arranged in a 0/45/0/-45/0 symmetric sequence, separated by a pine core (Fig. 4.37). These parameters are entered into the plate analysis code (described in Appendix G and included on the diskette accompanying the text) in the following exercise:

> plate
assign properties for lamina type 1...

enter modulus in fiber direction...
(enter -1 to stop): 55e9
enter modulus in transverse direction: 16e9
enter principal Poisson ratio: .26
enter shear modulus: 7.6e9
enter ply thickness: .15e-3

assign properties for lamina type 2...

enter modulus in fiber direction...
(enter -1 to stop): 11.5e9
enter modulus in transverse direction: .7e9
enter principal Poisson ratio: .3
enter shear modulus: .7e9
enter ply thickness: 1.25e-2

![Figure 4.36 Baseline ski design.](image-url)
assign properties for lamina type 3...

enter modulus in fiber direction...
    (enter -1 to stop): -1
define layup sequence, starting at bottom...
    (use negative material set number to stop)

enter material set number for ply number 1: 1
    enter ply angle: 0

enter material set number for ply number 2: 1
    enter ply angle: 45

enter material set number for ply number 3: 1
    enter ply angle: 0

enter material set number for ply number 4: 1
    enter ply angle: -45

enter material set number for ply number 5: 1
    enter ply angle: 0

enter material set number for ply number 6: 2
    enter ply angle: 0

enter material set number for ply number 7: 1
    enter ply angle: 0

enter material set number for ply number 8: 1
    enter ply angle: -45

enter material set number for ply number 9: 1
    enter ply angle: 0
enter material set number for ply number 10: 1
enter ply angle: 45

enter material set number for ply number 11: 1
enter ply angle: 0

enter material set number for ply number 12: -1

laminate stiffness matrix:

\[
\begin{bmatrix}
0.2117e+09 & 0.1404e+08 & 0.0000e+00 & -0.4922e+00 & -0.1025e+01 & -0.9766e-03 \\
0.1404e+08 & 0.4018e+08 & 0.0000e+00 & -0.9277e-02 & -0.1094e+00 & 0.0000e+00 \\
0.0000e+00 & 0.0000e+00 & 0.2518e+08 & -0.9766e-03 & 0.0000e+00 & -0.3467e-01 \\
-0.4922e+00 & -0.1025e-01 & -0.9766e-03 & 0.4835e+04 & 0.5350e+03 & 0.1186e+02 \\
-0.9277e-02 & -0.1094e+00 & 0.0000e+00 & 0.5350e+03 & 0.1493e+04 & 0.1186e+02 \\
-0.9766e-03 & 0.0000e+00 & -0.3467e-01 & 0.1186e+02 & 0.1186e+02 & 0.8357e+03 \\
\end{bmatrix}
\]

laminate compliance matrix:

\[
\begin{bmatrix}
0.4835e-08 & -0.1689e-08 & 0.2318e-22 & 0.5196e-12 & -0.2766e-12 & 0.2202e-14 \\
-0.1689e-08 & 0.2548e-07 & -0.4792e-22 & -0.3417e-12 & 0.1977e-11 & -0.2518e-13 \\
0.2324e-22 & -0.4780e-22 & 0.3971e-07 & 0.5652e-14 & -0.1511e-13 & 0.1648e-11 \\
0.5196e-12 & -0.3365e-12 & 0.5652e-14 & 0.2154e-03 & -0.7714e-04 & -0.1962e-05 \\
-0.2798e-12 & 0.1976e-11 & -0.1511e-13 & -0.7714e-04 & 0.6973e-03 & -0.8801e-05 \\
0.2246e-14 & -0.2524e-13 & 0.1648e-11 & -0.1962e-05 & -0.8801e-05 & 0.1197e-02 \\
\end{bmatrix}
\]

input tractions and moments...

\[
N_x: 0 \\
N_y: 0 \\
N_{xy}: 0 \\
M_x: 2100 \\
M_y: 0 \\
M_{xy}: 0
\]

midplane strains:

\[
\begin{align*}
\text{eps-xx} &= 0.1091e-08 \\
\text{eps-yy} &= -0.7176e-09 \\
\text{eps-xy} &= 0.1187e-10
\end{align*}
\]

rotations:

\[
\begin{align*}
\text{kappa-xx} &= 0.4523e+00 \\
\text{kappa-yy} &= -0.1620e+00 \\
\text{kappa-xy} &= -0.4120e-02
\end{align*}
\]

stresses:

\[
\begin{align*}
\text{ply} & & \text{sigma-1} & \text{sigma-2} & \text{sigma-12} \\
1 & & -0.1710e+09 & 0.5017e+07 & 0.2168e+06 \\
2 & & -0.2039e+08 & -0.5862e+08 & -0.3163e+08 \\
3 & & -0.1636e+09 & 0.4800e+07 & 0.2074e+06 \\
4 & & -0.1917e+08 & -0.5741e+08 & 0.3023e+08 \\
5 & & -0.1562e+09 & 0.4582e+07 & 0.1980e+06 \\
6 & & 0.1609e+02 & -0.2876e+00 & 0.6294e-02
\end{align*}
\]
The resulting ply stresses (given here in Pa) are well below the failure levels of the materials, and the curvature doesn’t seem excessive. This might therefore be a reasonable baseline starting point in the design. Of course, there is much left to be done, including the construction and resulting stresses at other points along the ski length; treatment of sideward and combined bending moments during various skiing maneuvers; and consideration of weight, manufacturability, and cost. And perhaps every bit as important as the technical aspects of design, it’s vital that a company starting up in the ski business be aware of the ins and outs of this very competitive market. One very competent high-tech composites company found they just couldn’t make money in skis because they “didn’t know the territory,” but a smaller company of dyed-in-the-wool skiers who bought the technology did all right.