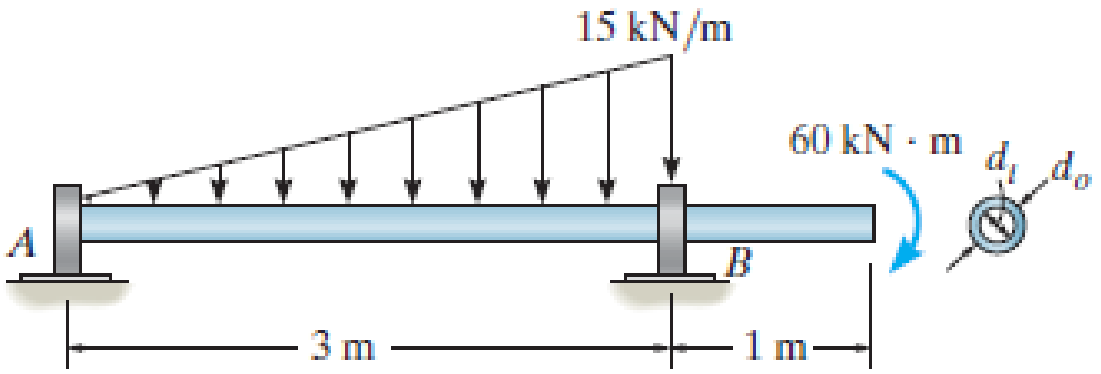
*6–84. The tubular shaft is to have a cross section such that its inner diameter and outer diameter are related by $d_i = 0.8d_o$. Determine these required dimensions if the allowable bending stress is $\sigma_{allow} = 155$ MPa.



Probs. 6–83/84

beam

```
u = symunit;
wf = findpoly(1, 'thru', [0 0], [3*u.m -15*u.kN/u.m]);
b = beam;
b = b.add('reaction', 'force', 'Ra', 0);
b = b.add('reaction', 'force', 'Rb', 3*u.m);
b = b.add('distributed', 'force', wf, [0 3]*u.m);
b = b.add('applied', 'moment', -60*u.kN*u.m, 4*u.m);
b.L = 4*u.m;
```

section properties

```
do = sym('do');
do_var = do;
di(do) = 0.8*do;
b.I = sympi/4*((do/2)^4-(di/2)^4);
```

elastic curve

```
[y dy m v w r] = b.elastic_curve([], 'factor'); %#ok
y
```

y(x) =

$$\begin{cases} -\dfrac{5000\ x\ (x-3\ \mathrm{m})\ (x+3\ \mathrm{m})\ (x^2+59\ \mathrm{m}^2)}{1107\ \mathrm{E}\ \mathrm{do}^4\ \pi}\ \dfrac{\mathrm{kN}}{\mathrm{m}^2} & \text{if } x \le 3\ \mathrm{m} \\ -\dfrac{40000\ (x-3\ \mathrm{m})\ (10\ x-13\ \mathrm{m})}{123\ \mathrm{E}\ \mathrm{do}^4\ \pi}\ \mathrm{kN\ m} & \text{if } 3\ \mathrm{m} < x \end{cases}$$

```
dy
```

dy(x) =

$$\begin{cases} -\dfrac{5000\ (5\ x^4+150\ x^2\ \mathrm{m}^2-531\ \mathrm{m}^4)}{1107\ \mathrm{E}\ \mathrm{do}^4\ \pi}\ \dfrac{\mathrm{kN}}{\mathrm{m}^2} & \text{if } x \le 3\ \mathrm{m} \\ -\dfrac{40000\ (20\ x-43\ \mathrm{m})}{123\ \mathrm{E}\ \mathrm{do}^4\ \pi}\ \mathrm{kN\ m} & \text{if } 3\ \mathrm{m} < x \end{cases}$$

```
m
```

m(x) =

$$\begin{cases} -\dfrac{5\ x\ (x^2+15\ \mathrm{m}^2)}{6}\ \dfrac{\mathrm{kN}}{\mathrm{m}^2} & \text{if } x \le 3\ \mathrm{m} \\ -60\ \mathrm{kN\ m} & \text{if } 3\ \mathrm{m} < x \end{cases}$$

```
v
```

v(x) =

$$\begin{cases} -\dfrac{5\ (x^2+5\ \mathrm{m}^2)}{2}\ \dfrac{\mathrm{kN}}{\mathrm{m}^2} & \text{if } x \le 3\ \mathrm{m} \\ 0 & \text{if } 3\ \mathrm{m} < x \end{cases}$$

```
w
```

w(x) =

$$\begin{cases} -5\ x\ \dfrac{\mathrm{kN}}{\mathrm{m}^2} & \text{if } x \le 3\ \mathrm{m} \\ 0 & \text{if } 3\ \mathrm{m} < x \end{cases}$$

```
addvar(y);
```

reactions

```
Ra = vpa(r.Ra) %#ok
```

Ra = $-12.5\ \mathrm{kN}$

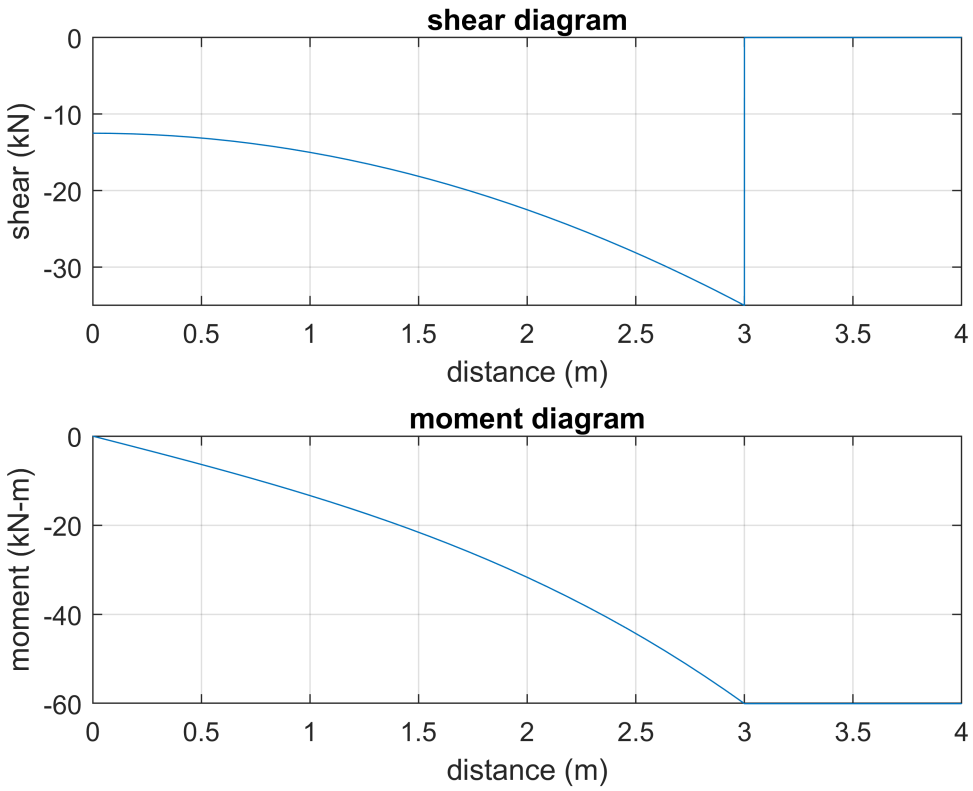
```
Rb = vpa(r.Rb) %#ok
```

Rb = 35.0 kN

```
clear Ra Rb;
```

shear and bending moment diagram

```
beam.shear_moment(m, v, [0 4], {'kN' 'm'});
```



minimum diameters

```
Mmax = m(3*u.m);
sigma_allow = 155*u.MPa;
c(do) = do/2;
assume(in(do, 'real') & do >= 0);
do = solve(sigma_allow == -Mmax*c/b.I);
do = combine(simplify(rewrite(do, u.mm), 'IgnoreAnalyticConstraints', true));
vpa(do, 5)
```

ans = 188.32 mm

```
clear ans;
clearassum;
```