

Section I BASICS

CHAPTER 1 INTRODUCTION

SOLUTION (1.1)

Free Body: Angle Bracket (Fig. S1.1)

$$(a) \sum M_B = 0; \quad F(20) - 15(10) - 4.8(20) = 0, \quad F = 12.3 \text{ kN} \leftarrow$$

$$(b) \sum F_x = 0: \quad R_{Bx} + 6.4 - F = 0, \quad R_{Bx} = 5.9 \text{ kN} \rightarrow$$

$$\sum F_y = 0: \quad R_{By} + 15 - 4.8 = 0, \quad R_{By} = 19.8 \text{ kN} \uparrow$$

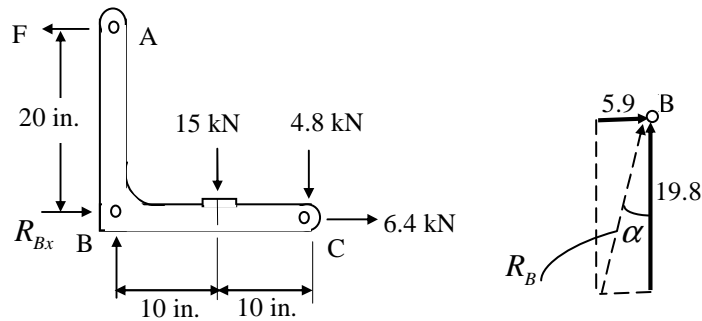
Thus

$$R_B = \sqrt{(5.9)^2 + (19.8)^2} = 20.7 \text{ kN}$$

and

$$\alpha = \tan^{-1} \frac{5.9}{19.8} = 15.9^\circ$$

Figure S1.1



SOLUTION (1.2)

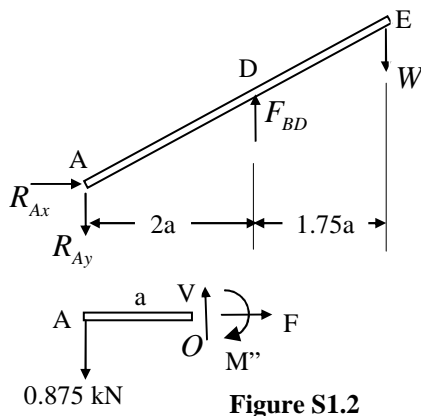


Figure S1.2

Free Body: Beam ADE (Fig. S1.2)

$$\sum M_A = 0: \quad -W(3.75a) + F_{BD}(2a) = 0,$$

$$F_{BD} = 1.875W \uparrow$$

$$\sum F_x = 0: \quad R_{Ax} = 0$$

$$\sum F_y = 0: \quad -R_{Ay} + F_{BD} - W = 0,$$

$$R_{Ay} = 0.875W \downarrow$$

Free-Body: Entire structure (Fig. S1.2)

$$\sum M_A = 0: \quad R_C(3a) - W(3.75a) = 0,$$

$$R_C = 1.25W \uparrow$$

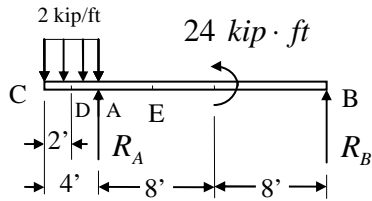
Free Body: Part AO (Fig. S1.2)

$$V = 0.875W \uparrow$$

$$F = 0$$

$$M = 0.875aW \curvearrowright$$

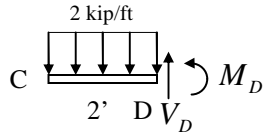
SOLUTION (1.3)



$$\sum M_A = 0: \quad R_B = 2.5 \text{ kips } \downarrow$$

$$\sum F_y = 0: \quad R_A = 10.5 \text{ kips } \uparrow$$

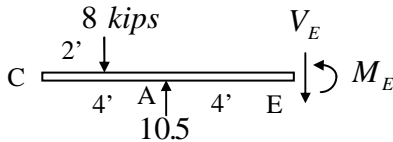
Segment CD



$$M_D = \frac{1}{2}(2)(2^2) = 4 \text{ kip} \cdot \text{ft}$$

$$V_D = 4 \text{ kips}$$

Segment CE

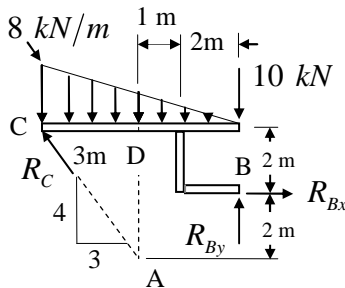


$$M_E = 8(6) - 10.5(4) = 6 \text{ kip} \cdot \text{ft}$$

$$V_E = 2.5 \text{ kips}$$

SOLUTION (1.4)

(a)



$$\sum M_B = 0: \quad 0.8R_C(6) - 0.6R_C(2) - 24(4) = 0$$

$$\therefore R_C = 26.667 \text{ kN}$$

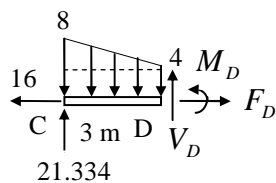
$$R_{Cx} = 16 \text{ kN}, \quad R_{Cy} = 21.334 \text{ kN}$$

Then

$$\sum F_x = 0: \quad R_{Bx} = 16 \text{ kN}$$

$$\sum F_y = 0: \quad R_{By} = 12.66 \text{ kN}$$

(b) Segment CD

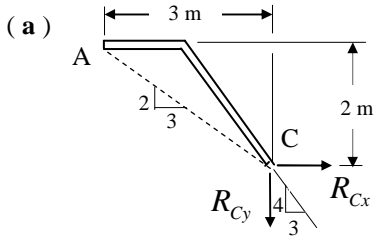


$$M_D = 21.334(3) - 12(1.5) - 6(2) = 34 \text{ kN} \cdot \text{m}$$

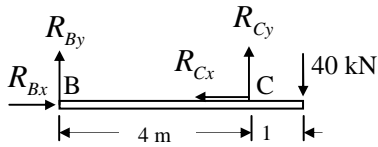
$$F_D = 16 \text{ kN}$$

$$V_D = 21.334 - 18 = 3.334 \text{ kN}$$

SOLUTION (1.5)



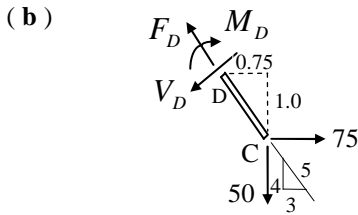
$$\sum M_A = 0: \quad R_{Cx} = \frac{3}{2} R_{Cy}$$



$$\sum M_B = 0: \quad 40(5) - 4R_{Cy} = 0 \quad R_{Cy} = 50 \text{ kN } \uparrow$$

Then $R_{Cx} = 75 \text{ kN } \leftarrow$

$$R_{By} = 10 \text{ kN } \uparrow, \quad R_{Bx} = 75 \text{ kN } \leftarrow$$

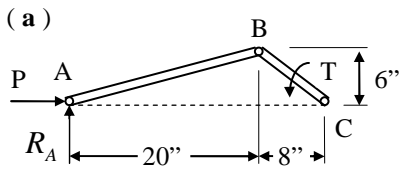


$$F_D = 75\left(\frac{3}{5}\right) + 50\left(\frac{4}{5}\right) = 85 \text{ kN}$$

$$V_D = 75\left(\frac{4}{5}\right) - 50\left(\frac{3}{5}\right) = 30 \text{ kN}$$

$$M_D = 75(1) - 50(0.75) = 37.5 \text{ kN} \cdot \text{m}$$

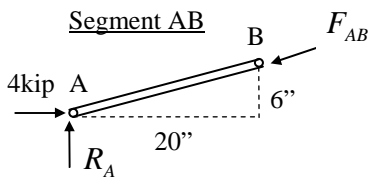
SOLUTION (1.6)



Free body entire connection

$$\sum M_C = 0: \quad R_A(28) - T = 0$$

$$T = 28R_A$$



$$AB = \sqrt{20^2 + 6^2} = 20.88 \text{ in.}$$

$$\sum M_B = 0: \quad 4(6) - R_A(20) = 0$$

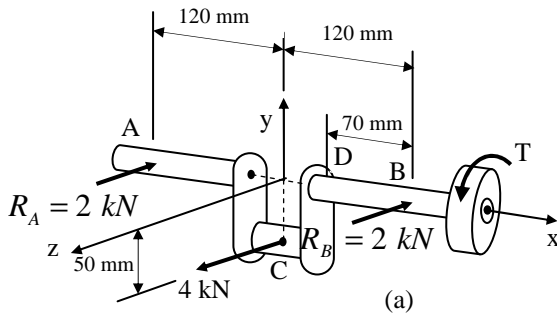
$$R_A = 1.2 \text{ kips}$$

and

$$T = 33.6 \text{ kip} \cdot \text{in.}$$

$$(b) \quad \sum F_x = 0: \quad 4 - \frac{20}{20.88} F_{AB} = 0, \quad F_{AB} = 4.176 \text{ kips}$$

SOLUTION (1.7)



Free Body: Entire Crankshaft (Fig. S1.7a)

(a) From symmetry: $R_A = R_B$

$$\sum F_z = 0: \quad R_A = R_B = 2 \text{ kN } \nearrow$$

$$\sum M_x = 0: \quad -4(0.05) + T = 0,$$

$$T = 0.2 \text{ kN} \cdot \text{m} = 200 \text{ N} \cdot \text{m}$$

(CONT.)

1.7 (CONT.)

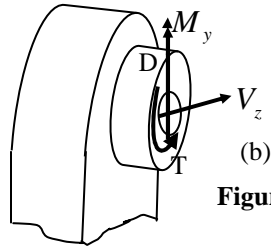
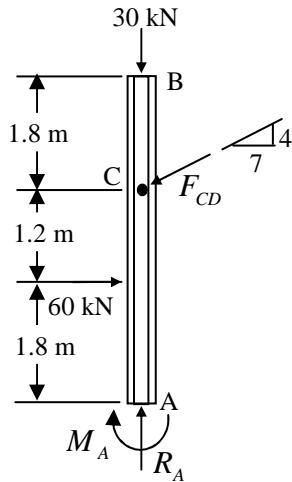


Figure S 1.7

(b) Cross Section at D (Fig. S1.7b)

$$\begin{aligned}
 V_z &= 2 \text{ kN} \nearrow \\
 T &= 200 \text{ N} \cdot \text{m} \rightarrow \\
 M_y &= 2(0.07) = 0.14 \text{ kN} \cdot \text{m} \\
 &= 140 \text{ N} \cdot \text{m} \uparrow
 \end{aligned}$$

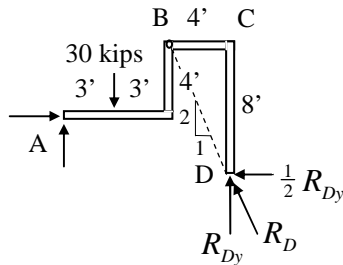
SOLUTION (1.8)



Free-Body Diagram, Beam AB

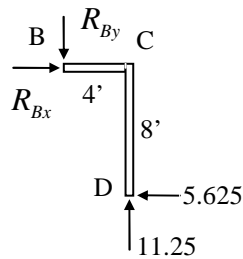
$$\begin{aligned}
 \sum F_x = 0: & \quad -\frac{7}{\sqrt{65}} F_{CD} + 60 = 0, \quad F_{CD} = 69.11 \text{ kN} \\
 \sum F_y = 0: & \quad R_A - \frac{4}{\sqrt{65}} F_{CD} - 30 = 0, \quad R_A = 64.3 \text{ kN} \uparrow \\
 \sum M_A = 0: & \quad -60(1.8) + \frac{7}{\sqrt{65}} F_{CD}(3) - M_A = 0, \\
 & \quad M_A = 72 \text{ kN} \cdot \text{m}
 \end{aligned}$$

SOLUTION (1.9)



Free body entire frame

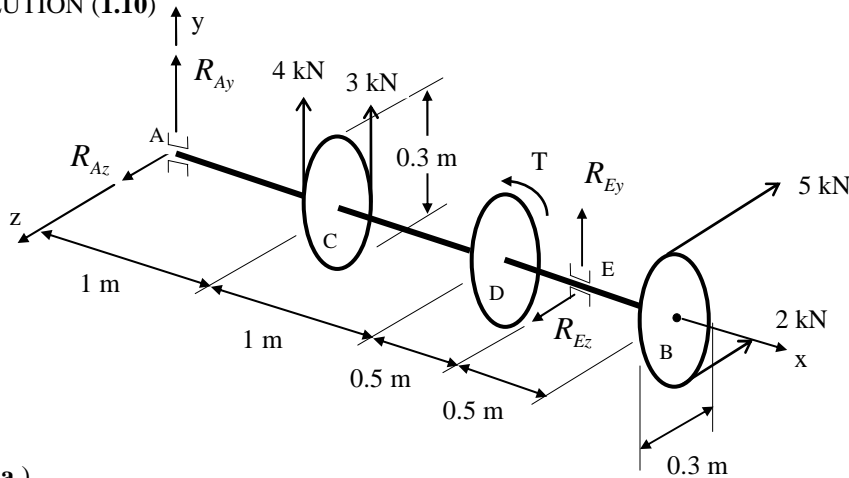
$$\begin{aligned}
 \sum M_A = 0: & \quad -30(3) - \frac{1}{2} R_{Dy}(4) + R_{Dy}(10) = 0 \\
 & \quad R_{Dy} = 11.25 \text{ kips}, \quad R_{Dx} = 5.625 \text{ kips}
 \end{aligned}$$



Free body BCD

$$\begin{aligned}
 \sum F_x = 0: & \quad R_{Bx} = 5.625 \text{ kips} \\
 \sum F_y = 0: & \quad R_{By} = 11.25 \text{ kips} \\
 R_B &= \sqrt{5.625^2 + 11.25^2} = 12.58 \text{ kips}
 \end{aligned}$$

SOLUTION (1.10)



(a)

$$\sum M_x = 0: \quad 3(0.15) - 4(0.15) + T - 5(0.15) + 2(0.15) = 0$$

or $T = 0.6 \text{ kN} \cdot \text{m}$

(b)

$$\sum M_z = 0: \quad (4 + 3)(1) + R_{Ey}(2.5) = 0, \quad R_{Ey} = -2.8 \text{ kN}$$

$$\sum M_y = 0: \quad -R_{Ez}(2.5) + (5 + 2)(3) = 0, \quad R_{Ez} = 8.4 \text{ kN}$$

$$\sum F_y = 0: \quad R_{Ay} + 4 + 3 + R_{Ey} = 0, \quad R_{Ay} = -4.2 \text{ kN}$$

$$\sum F_z = 0: \quad R_{Az} + R_{Ez} - 5 - 2 = 0, \quad R_{Az} = -1.4 \text{ kN}$$

Thus $R_A = \sqrt{4.2^2 + 1.4^2} = 4.427 \text{ kN}$

$R_E = \sqrt{2.8^2 + 8.4^2} = 8.854 \text{ kN}$

SOLUTION (1.11)

(a) Free-body Diagrams, Arm BC and shaft AB

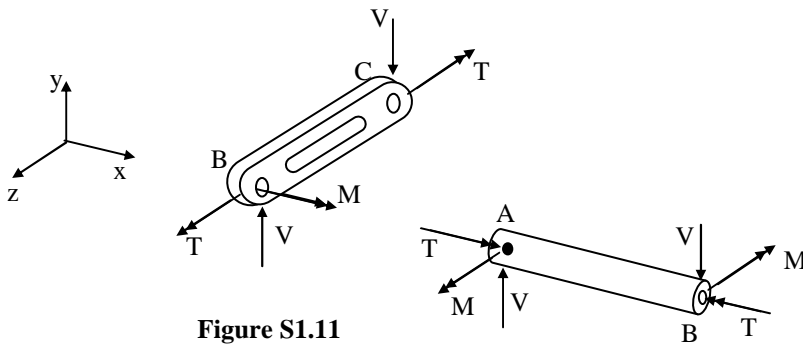


Figure S1.11

(b) At C:

$$V = -2 \text{ kN} \quad T = -50 \text{ N} \cdot \text{m}$$

At end B of arm BC:

$$V = 2 \text{ kN} \quad T = 50 \text{ N} \cdot \text{m} \quad M = 200 \text{ N} \cdot \text{m}$$

At end B of shaft AB:

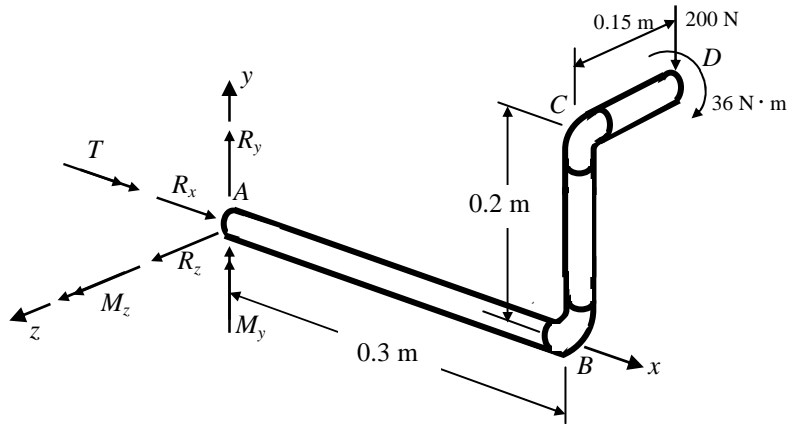
$$V = -2 \text{ kN} \quad T = -200 \text{ N} \cdot \text{m} \quad M = -50 \text{ N} \cdot \text{m}$$

At A:

$$V = 2 \text{ kN} \quad T = 200 \text{ N} \cdot \text{m} \quad M = 300 \text{ N} \cdot \text{m}$$

SOLUTION (1.12)

Free Body: Entire Pipe



Reactional forces at point A:

$$\sum F_x = 0: R_x = 0$$

$$\sum F_y = 0: R_y - 200 = 0, \quad R_y = 200 \text{ N}$$

$$\sum F_z = 0: R_z = 0$$

Moments about point A:

$$\sum M_x = 0: T - 200(0.15) = 0, \quad T = 30 \text{ N} \cdot \text{m}$$

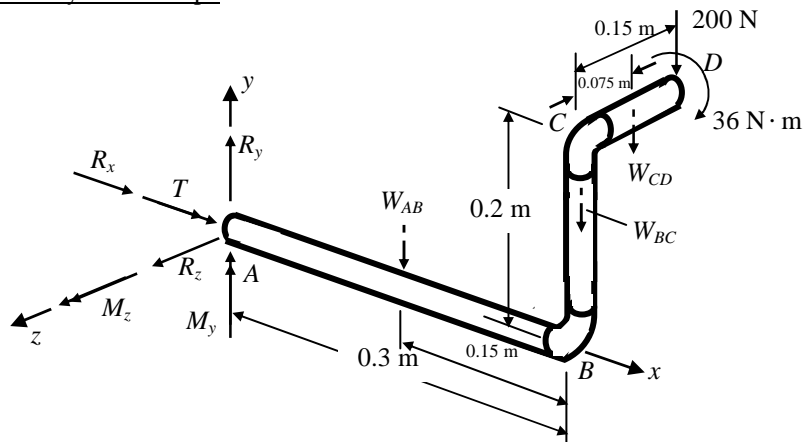
$$\sum M_y = 0: M_y = 0$$

$$\sum M_z = 0: M_z - 200(0.3) - 36 = 0, \quad M_z = 96 \text{ N} \cdot \text{m}$$

The reactions act in the directions shown on the free-body diagram.

SOLUTION (1.13)

Free Body : Entire Pipe



(CONT.)

1.13 (CONT.)

We have 1 lb/ft=14.5939 N/m (Table A.1).

Thus, for 3 in. or 75-mm pipe (Table A.4): 14.5939(7.58)=110.62 N/m

Total weights of each part acting at midlength are:

$$W_{AB} = 110.62(0.3) = 33.2 \text{ N}$$

$$W_{BC} = 110.62(0.2) = 22.1 \text{ lb}$$

$$W_{CD} = 110.62(0.15) = 16.6 \text{ N}$$

Reactional forces at point A:

$$\sum F_x = 0: \quad R_x = 0$$

$$\sum F_y = 0: \quad R_y - W_{AB} - W_{BC} - W_{CD} - 200 = 0, \quad R_y = 271.9 \text{ N} \quad \blacktriangleleft$$

$$\sum F_z = 0: \quad R_z = 0$$

Moments about point A:

$$\sum M_x = 0: \quad T - W_{CD}(0.075) - 10(0.15) = 0, \quad T = 2.745 \text{ N} \cdot \text{m}$$

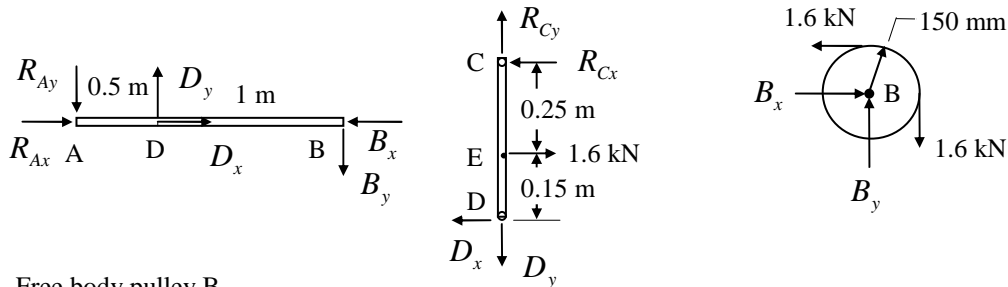
$$\sum M_y = 0: \quad M_y = 0$$

$$\sum M_z = 0: \quad M_z - (200 + W_{CD} + W_{BC})(0.3) - W_{AB}(0.15) - 36 = 0$$

$$M_z = 112.6 \text{ N} \cdot \text{m}. \quad \blacktriangleleft$$

SOLUTION (1.14)

(a)



Free body pulley B

$$\sum F_x = 0: \quad B_x = 1.6 \text{ kN} \rightarrow$$

$$\sum F_y = 0: \quad B_y = 1.6 \text{ kN} \uparrow$$

Free body CED

$$\sum M_D = 0: \quad R_{Cx}(0.4) - 1.6(0.15) = 0, \quad R_{Cx} = 0.6 \text{ kN} \leftarrow$$

$$\sum F_x = 0: \quad -D_x - 0.6 + 1.6 = 0, \quad D_x = 1 \text{ kN} \leftarrow$$

$$\sum F_y = 0: \quad R_{Cy} = D_y$$

Free body ADB

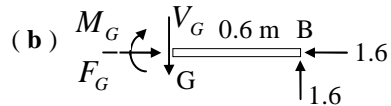
$$\sum M_A = 0: \quad D_y(0.5) - B_y(1.5) = 0, \quad D_y = 4.8 \text{ kN}, \quad R_{Cy} = 4.8 \text{ kN} \uparrow$$

$$\sum F_x = 0: \quad -R_{Ay} + D_y - B_y = 0, \quad R_{Ay} = 3.2 \text{ kN} \downarrow \quad \blacktriangleleft$$

(CONT.)

1.14 (CONT.)

$$\sum F_x = 0: \quad R_{Ax} + D_x - B_x = 0, \quad R_{Ax} = 0.6 \text{ kN} \rightarrow$$

(b)  $M_G = 1.6(0.6) = 960 \text{ N} \cdot \text{m}, \quad V_G = 1.6 \text{ kN}$
 $F_G = 1.6 \text{ kN}$

SOLUTION (1.15)

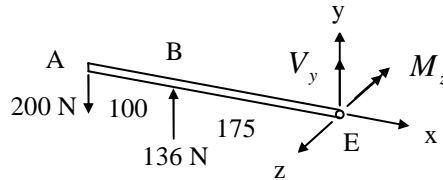
Free body entire rod

$$\sum M_x = 0: \quad R_{Dy}(0.25) - 300(0.1), \quad R_{Dy} = 120 \text{ N} \uparrow$$

$$\left(\sum M_z\right)_C = 0: \quad -200(0.35) + R_{By}(0.25) + (300 - 120)(0.2) = 0$$

$$R_{By} = 136 \text{ N} \uparrow$$

Free body ABE



$$\left(\sum M_z\right)_E = 0: \quad -M_z + 200(0.275) - 136(0.175) = 0, \quad M_z = 31.2 \text{ N} \cdot \text{m}$$

$$\sum F_y = 0: \quad V_y = 200 - 136 = 64 \text{ N}$$

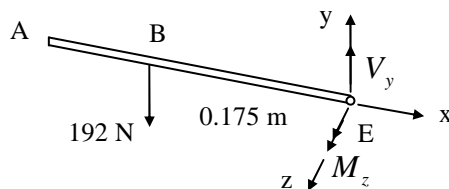
SOLUTION (1.16)

Free body entire rod:

$$\sum M_x = 0: \quad R_{Dy}(0.25) - 400(0.1) = 0, \quad R_{Dy} = 160 \text{ N} \uparrow$$

$$\left(\sum M_z\right)_C = 0: \quad R_{By}(0.25) + (400 - 160)(0.2) = 0, \quad R_{By} = 192 \text{ N} \downarrow$$

Segment ABE



At point E:

$$M_z = -192(0.175) = -33.6 \text{ N} \cdot \text{m}$$

$$V_y = 192 \text{ N}$$

SOLUTION (1.17)

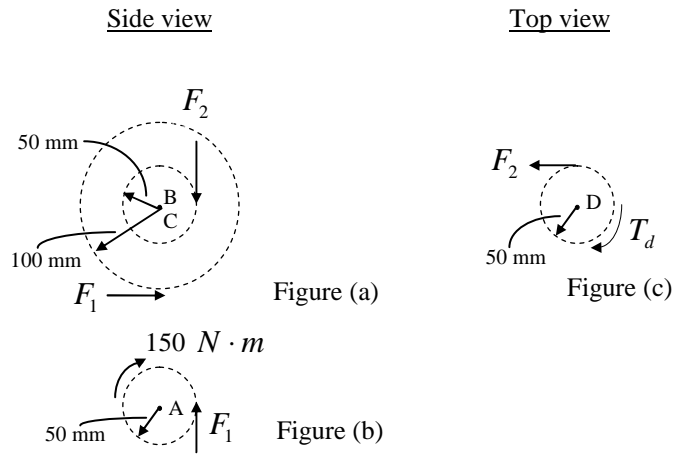
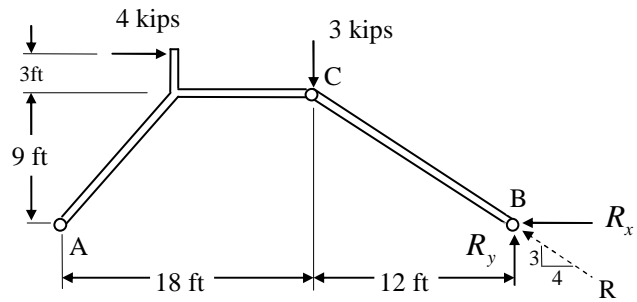


Fig. (b): $\sum M_A = 0: F_1(0.05) - 150 = 0, \quad F_1 = 3 \text{ kN}$
 Fig. (a): $\sum M_B = 0: F_1(0.1) - F_2(0.05) = 0, \quad F_2 = 6 \text{ kN}$
 Fig. (c): $\sum M_D = 0: F_2(0.05) - T_d = 0, \quad T_d = 0.3 \text{ kN} \cdot \text{m}$ ◀

SOLUTION (1.18)



Free body-entire frame

$$\sum M_A = 0: R_y(30) - 3(18) - 4(12) = 0, \quad R_y = 3.4 \text{ kips}$$

Free body-member BC

$$\sum M_C = 0: R_x(9) - R_y(12) = 0$$

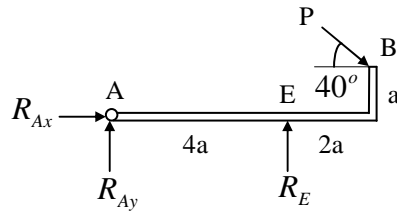
and

$$R_x = \frac{4}{3}(3.4) = 4.533 \text{ kips}$$

Thus

$$F_{BC} = R = \sqrt{(4.533)^2 + (3.4)^2} = 5.666 \text{ kips}$$
 ◀

SOLUTION (1.19)



Free body-member AB

$$\sum M_A = 0:$$

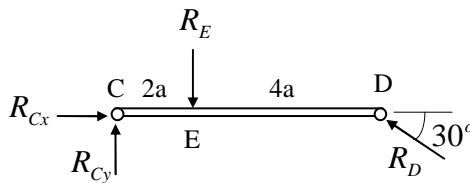
$$R_E(4a) - P \cos 40^\circ(a) - P \sin 40^\circ(6a) = 0$$

$$\therefore R_E = 1.156P$$

$$\sum F_x = 0: R_{Ax} = P \cos 40^\circ = 0.766P \leftarrow$$

$$\sum F_y = 0: R_{Ay} + 1.156P - P \sin 40^\circ = 0, R_{Ay} = 0.513P \downarrow$$

Free body-member CD



$$\sum M_D = 0: R_E(4a) - R_{Cy}(6a) = 0$$

$$\therefore R_{Cy} = 0.771P \uparrow$$

$$\sum M_C = 0: R_D \sin 30^\circ(6a) - R_E(2a) = 0, R_D = 0.771P$$

$$\sum F_x = 0: R_{Cx} = R_D \cos 30^\circ = 0.668P \rightarrow$$

SOLUTION(1.20)

(a) Power = $P = (pA)(L)(n/60)$

$$= (1.2)(2100)(0.06)\left(\frac{1500}{60}\right) = 3.78 \text{ kW}$$

$$\text{Power required} = \frac{P}{e} = \frac{3.78}{0.9} = 4.2 \text{ kW}$$

(b) Use Eq.(1.15),

$$T = \frac{9549 \text{ kW}}{n} = \frac{9549(4.2)}{1500} = 26.74 \text{ N} \cdot \text{m}$$

SOLUTION (1.21)

Refer to App. A.1: $65 \text{ mph} = 65(5280)/60 = 5720 \text{ fpm}$.

(a) From Eq. (1.17), the drag force equals,

$$F_d = \frac{33,000 \text{ hp}}{v} = \frac{33,000(18)}{5720} = 103.4 \text{ lb}$$

See: Fig. P1.21:

$$\sum F_x = 0: F = 103.4 \text{ lb}$$

It follows that

$$\sum M_A = 0: -Wa + F_d c + R_f L = 0$$

or

$$-3.2(60) + (0.1034)(25) + R_f(110) = 0$$

(CONT.)

1.21 (CONT.)

Solving,

$$R_f = 1.722 \text{ kips}$$

and

$$\sum F_y = 0: R_r - 3.2 + 1.722 = 0$$

or

$$R_r = 1.478 \text{ kips}$$

(b)

We have $V = 0$, $F_d = 0$, $F = 0$.

See Fig. P1.21:

$$\sum M_A = 0: Wa + R_f L = 0$$

Thus

$$R_f = \frac{a}{L} W = \frac{60}{110} (3.2) = 1.745 \text{ kips}$$

So, $\sum F_y = 0$ gives

$$R_r = W - R_f = 3.2 - 1.745 = 1.455 \text{ kips}$$

SOLUTION (1.22)

Refer to Solution of Prob. 1.21. Now we have $W_t = 3.2 + 1.2 = 4.4 \text{ kips}$ and friction force $F = 103.4 \text{ lb}$ acts at point A.

(a) See: Fig. 1.21 (with $W = W_t$):

$$\sum M_A = -4.4(60) + (0.1034)(25) + R_f(110) = 0$$

from which

$$R_f = 2.377 \text{ kips}$$

and

$$R_r = 4.4 - 2.377 = 2.023 \text{ kips}$$

(b) $V = 0$, $F_d = 0$, $F = 0$, as before,

$$\sum M_A = 0: R_f = \frac{a}{L} W_t = \frac{60}{110} (4.4) = 2.4 \text{ kips}$$

and

$$R_r = W_t - R_f = 4.2 - 2.4 = 1.8 \text{ kips}$$

SOLUTION (1.23)

(a) Free-Body Diagram: Gears (Fig. S1.23).

Applying Eq. (1.15):

$$T_{AC} = \frac{9550P}{n} = \frac{9550(35)}{500} = 668.5 \text{ N} \cdot \text{m}$$

Therefore,

$$F = \frac{T_A}{r_A} = \frac{668.5}{0.125} = 5.348 \text{ kN}$$

(CONT.)

1.23 (CONT.)

(b) $T_{DE} = Fr_D = 5,348(0.075) = 401.1 \text{ N} \cdot \text{m}$ ◀

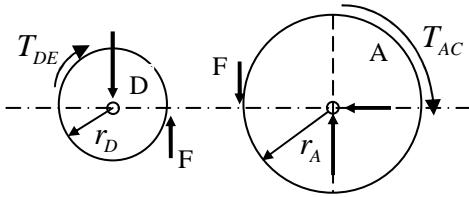


Figure S1.23

SOLUTION (1.24)

From Eq. (1.17), we obtain $T=63,000 \text{ hp/n}$. Thus

For input shaft

$$T = \frac{63000(30)}{1800} = 1.05 \text{ kip} \cdot \text{in.}$$
 ◀

For output shaft

$$T = \frac{63000(27)}{425} = 4.0 \text{ kip} \cdot \text{in.}$$
 ◀

Equation (1.14) gives

$$e = \frac{27}{30} = 0.9 = 90 \%$$
 ◀

SOLUTION (1.25)

(a) Referring to Eq. (1.12):

$$\begin{aligned} \text{power output} &= Fs\left(\frac{N}{60}\right) = 500 \times 2.5\left(\frac{150}{60}\right) \\ &= 3,125 \text{ lb} \cdot \text{in./s} \end{aligned}$$

(b) Using Eq. (1.14), power transmitted by the shaft:

$$\text{power input} = 3,125/(0.88) = 3,551 \text{ lb} \cdot \text{in./s}$$

SOLUTION (1.26)

Equation (1.10) becomes

$$\Delta E_k = \frac{1}{2} I (\omega_{\max}^2 - \omega_{\min}^2) \tag{1}$$

Here, mass moment inertia with 5 percent added:

$$\begin{aligned} I &= (1.05) \frac{\pi}{32} (d_o^4 - d_i^4) \cdot l \rho \quad (\text{Table A-5}) \\ &= 1.05 \frac{\pi}{32} (0.4^4 - 0.3^4)(0.1)(7,200) \\ &= 1.299 \text{ kg} \cdot \text{m}^2 \end{aligned}$$

$$\omega_{\max} = 1200\left(\frac{1}{60}\right) = 20 \text{ rps} = 125.7 \text{ rad/s}$$

$$\omega_{\min} = 1100\left(\frac{1}{60}\right) = 18.3 \text{ rps} = 115 \text{ rad/s}$$

Equation (1) is therefore

$$\begin{aligned} \Delta E_k &= \frac{1}{2} (1.299)(125.7^2 - 115^2) \\ &= 1,673 \text{ J} \end{aligned}$$
 ◀

SOLUTION (1.27)

Final length of the wire:

$$L_{AC'} = \sqrt{(80)^2 + (50.4)^2} = 94.55242 \text{ in.}$$

Initial length of the wire is

$$L_{AC} = \sqrt{(80)^2 + (50)^2} = 94.33981 \text{ in.}$$

Hence, Eq. (1.20):

$$\begin{aligned}\epsilon_{AC} &= \frac{L_{AC'} - L_{AC}}{L_{AC}} = \frac{94.55242 - 94.33981}{94.33981} \\ &= 0.00225 = 2250 \mu\end{aligned}$$

◀

SOLUTION (1.28)

$$(a) \quad \epsilon_c = \frac{2\pi(r+\Delta r) - 2\pi r}{2\pi r} = \frac{\Delta r}{r}$$

$$(\epsilon_c)_i = \frac{0.3}{150} = 2000 \mu$$

◀

$$(\epsilon_c)_o = \frac{0.2}{250} = 800 \mu$$

$$(b) \quad \epsilon_r = \frac{\Delta r_o - \Delta r_i}{r_o - r_i} = \frac{0.3 - 0.2}{250 - 150} = 1000 \mu$$

◀

SOLUTION (1.29)

$$L_{OB} = d, \quad L_{AB} = L_{BC} = d\sqrt{2} = 1.41421d$$

$$(a) \quad \epsilon_{OB} = \frac{0.0012d}{d} = 1200\mu$$

◀

$$(b) \quad L_{AB'} = L_{CB'} = [d^2 + (1.0012d)^2]^{1/2} = 1.41506d$$

◀

$$\epsilon_{AB} = \epsilon_{BC} = \frac{1.41506 - 1.41421}{1.41421} = 601 \mu$$

◀

$$(c) \quad CAB = \tan^{-1}\left(\frac{1.0012d}{d}\right) = 45.0344^\circ$$

Increase in angle CAB is $45.0344 - 45 = 0.0344^\circ$.

Thus

$$\gamma = 0.0344\left(\frac{\pi}{180}\right) = 600 \mu$$

◀

SOLUTION (1.30)

$$(a) \quad \epsilon_x = \frac{0.8 - 0.5}{250} = 1200 \mu \quad \epsilon_y = \frac{-0.4 - 0}{200} = -2000 \mu$$

◀

$$\begin{aligned}(b) \quad L'_{AD} &= L_{AD} + \epsilon_x L_{AD} = L_{AD}(1 + \epsilon_x) \\ &= 250(1.0012) = 250.3 \text{ mm}\end{aligned}$$

◀

SOLUTION (1.31)

$$\Delta L_{AB} = 800(10^{-6})150 = 120(10^{-3}) \text{ mm}$$

$$\Delta L_{AD} = 1000(10^{-6})200 = 200(10^{-3}) \text{ mm}$$

We have

$$L_{BD}^2 = L_{AB}^2 + L_{AD}^2$$

$$2L_{BD}\Delta L_{BD} = 2L_{AB}\Delta L_{AB} + 2L_{AD}\Delta L_{AD}$$

or

$$\Delta L_{BD} = \frac{L_{AB}}{L_{BD}} \Delta L_{AB} + \frac{L_{AD}}{L_{BD}} \Delta L_{AD} \quad (1)$$

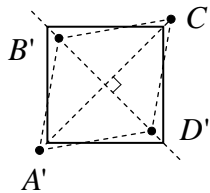
$$= \left[\frac{150}{250}(120) + \frac{200}{250}(200) \right] 10^{-3} = 0.232 \text{ mm}$$

SOLUTION (1.32)

$$AC = BD = \sqrt{300^2 + 300^2} = 424.26 \text{ mm}$$

$$B'D' = 424.26 - 0.5 = 423.76 \text{ mm}, \quad A'C' = 424.26 + 0.2 = 424.46 \text{ mm}$$

Geometry: $A'B' = A'D'$

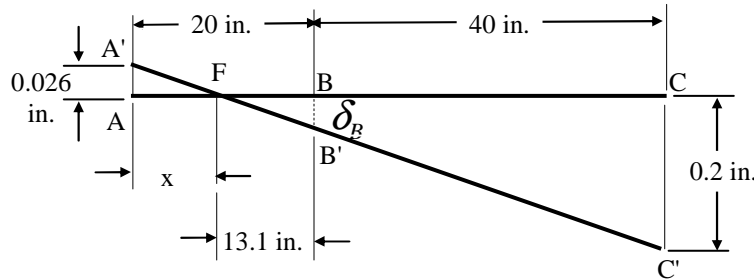


$$\epsilon_x = \epsilon_y = \frac{A'D' - AD}{AD}$$

$$= \frac{\left[\left(\frac{423.76}{2} \right)^2 + \left(\frac{424.46}{2} \right)^2 \right]^{1/2} - 300}{300} = -363 \mu$$

$$\gamma_{xy} = \frac{\pi}{2} - \beta = \frac{\pi}{2} - 2 \tan^{-1} \frac{423.76/2}{424.46/2} = 1651 \mu$$

SOLUTION (1.33)



We have

$$\begin{aligned} \delta_{AD} &= \epsilon_{AD} L_{AD} \\ &= 800 \times 10^{-6} (32) \\ &= 0.026 \text{ in.} \end{aligned}$$

From triangles $A'AF$ and $C'CF$:

$$\frac{0.026}{x} = \frac{0.2}{60-x}, \quad x = 6.9 \text{ in.}$$

From triangles $B'BF$ and $C'CF$:

$$\frac{13.1}{\delta_B} = \frac{53.1}{0.2}, \quad \delta_B = 0.049 \text{ in.} = -\delta_{BE} \text{ (contraction)}$$

Therefore

$$\begin{aligned} \epsilon_{BE} &= \frac{-\delta_{BE}}{L_{BE}} = \frac{0.049}{40} = -1225(10^{-6}) \\ &= -1,225 \mu \end{aligned}$$

SOLUTION (1.34)

$$\begin{aligned} \text{(a)} \quad \varepsilon_x &= \frac{0.006}{50} = 120 \mu & \varepsilon_y &= \frac{-0.004}{25} = -160 \mu \\ \gamma_{xy} &= -1000 + 200 = -800 \mu \end{aligned} \quad \blacktriangleleft$$

$$\begin{aligned} \text{(b)} \quad L'_{AB} &= L_{AB}(1 + \varepsilon_y) = 25(1 - 0.00016) = 24.996mm \\ L'_{AD} &= L_{AD}(1 + \varepsilon_x) = 50(1 + 0.00012) = 50.006mm \end{aligned} \quad \blacktriangleleft$$

End of Chapter 1

CHAPTER 2 MATERIALS

SOLUTION (2.1)

$$A_0 = \frac{\pi}{4}(0.5)^2 = 196.35(10^{-3}) \text{ in.}^2, \quad A_f = \frac{\pi}{4}(0.5 - 0.00024)^2 = 196.16(10^{-3}) \text{ in.}^2$$

$$\text{We have } \epsilon_a = \frac{12(10^{-3})}{8} = 1500 \mu, \quad \epsilon_t = \frac{0.24(10^{-3})}{0.5} = 480 \mu$$

Thus

$$S_p = \frac{P}{A_0} = \frac{4(10^3)}{196.35(10^{-3})} = 20.37 \text{ ksi}$$

$$E = \frac{S_p}{\epsilon_a} = \frac{20.37(10^3)}{1500(10^{-6})} = 13.58(10^6) \text{ psi}, \quad \nu = \frac{\epsilon_t}{\epsilon_a} = 0.32 \quad \blacktriangleleft$$

Also

$$\% \text{ elongation} = \frac{12(10^{-3})}{8}(100) = 0.15$$

$$\% \text{ reduction in area} = \frac{196.35 - 196.16}{196.35}(100) = 0.097 \quad \blacktriangleleft$$

SOLUTION (2.2)

Normal stress is

$$\sigma = \frac{P}{A} = \frac{500}{\frac{\pi(1/8)^2}{4}} = 4744 \text{ ksi}$$

This is below the yield strength of 50 ksi (Table B.1).

We have

$$\epsilon = \frac{\delta}{L} = \frac{0.3}{18.5 \times 12} = 0.001351 = 1351 \mu$$

Hence

$$E = \frac{\sigma}{\epsilon} = \frac{40,744}{135(10^{-6})} = 30 \times 10^6 \text{ psi} \quad \blacktriangleleft$$

SOLUTION (2.3)

The cross-sectional area: $A = w_o t_o = 0.5(0.25) = 0.125 \text{ in.}^2$

(a) Axial strain and axial stress are

$$\epsilon_a = \frac{0.00331}{2.5} = 0.01324 = 1324 \mu$$

$$\sigma_a = \frac{P}{A} = \frac{4.8}{0.125} = 38.4 \text{ ksi}$$

Because $\sigma_a < S_y$ (See Table B.1), Hooke's Law is valid.

(b) Modulus of elasticity,

$$E = \frac{\sigma_a}{\epsilon_a} = \frac{38,400}{1324(10^{-6})} = 29 \times 10^6 \text{ psi}$$

(c) Decrease in the width and thickness

$$\Delta w = \nu w_o = 0.3(0.5) = 0.15 \text{ in.} \quad \blacktriangleleft$$

$$\Delta t = \nu t_o = 0.3(0.24) = 0.072 \text{ in.}$$