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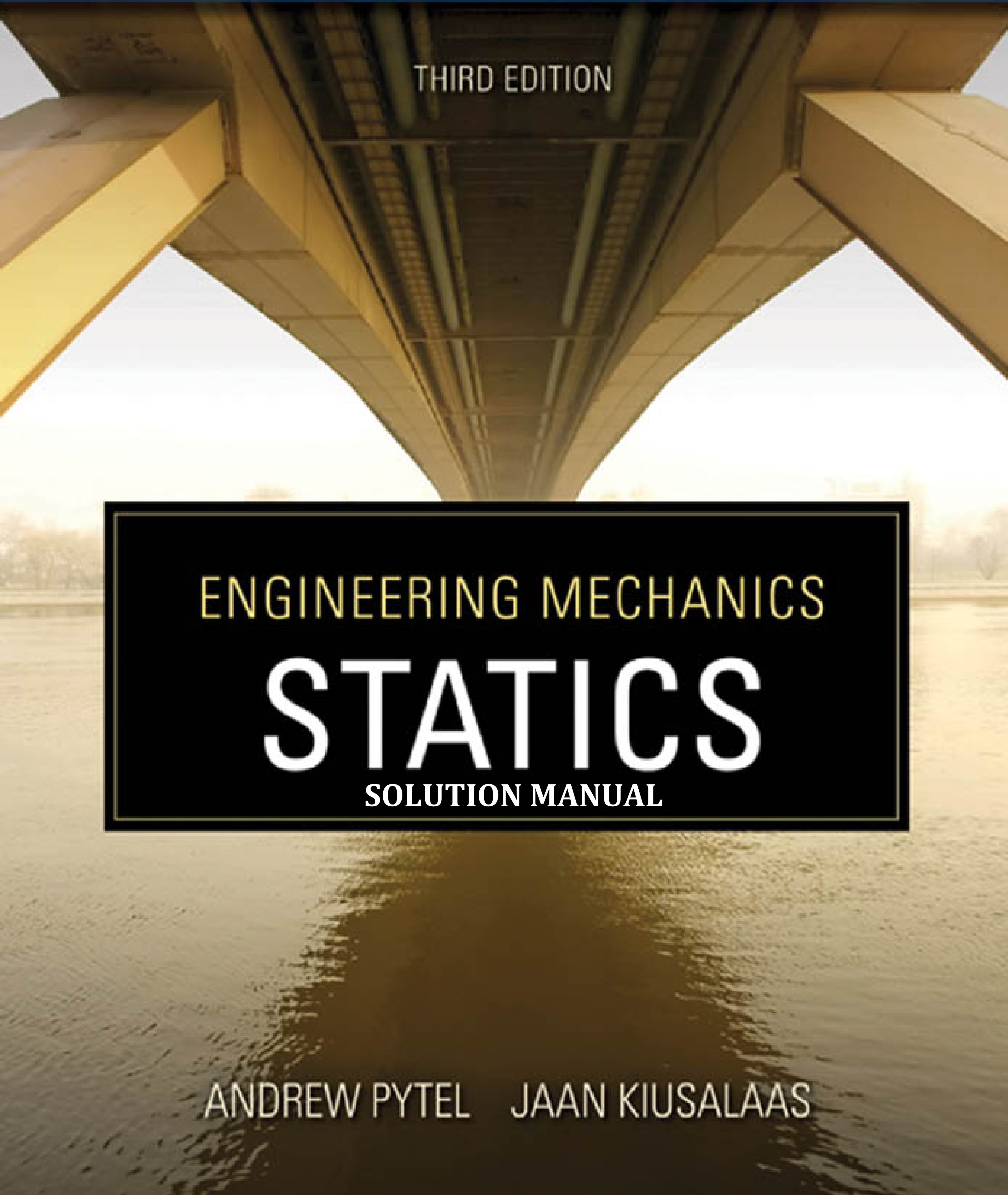

THIRD EDITION

ENGINEERING MECHANICS
STATICS

SOLUTION MANUAL

ANDREW PYTEL   JAAN KIUSALAAS

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Engineering Mechanics

Statics

Third Edition, SI

SOLUTION MANUAL

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Contents

Chapter 1

1.1

(a) $\mathbf{m} = \dfrac{\mathbf{150\ N}}{\mathbf{1.64}} = \mathbf{91.46}\ \text{kg}$ ◆

(b) $\mathbf{W = mg} = (\mathbf{91.46})(\mathbf{9.81}) = \mathbf{897.2}\ \text{N}$ ◆

1.2

$$\mathbf{W = \rho g V = (7850)(9.81)\pi(0.06)^2(0.120) = 104.51\ N}$$

$$\text{W} = \boldsymbol{mg} \quad \mathbf{104.51} = (\boldsymbol{m}) \times \mathbf{9.81} \quad \boldsymbol{m} = \frac{\mathbf{104.51}}{\mathbf{9.81}} = \mathbf{1065}\ \text{kg}$$ ◆

1.3

(a) $\mathbf{40000}\ \text{N}\cdot\text{cm} = \mathbf{40000}\ \text{N}\cdot\text{cm} \times \dfrac{\mathbf{1}\ \text{kN}}{\mathbf{1000N}} \times \dfrac{\mathbf{1m}}{\mathbf{100}\text{cm}} = \mathbf{0.4}\ \text{kN}\cdot\text{m}$ ◆

(b) $\mathbf{1}\ \text{bar} = \mathbf{10^5}\text{Pa} = \mathbf{10^5}\text{N/m}^2 \times \dfrac{\mathbf{1}\ \text{kn/m}^2}{\mathbf{1000}\ \text{N/m}^2} = 100\text{kN/m}^2 = \mathbf{100}\ \text{kPa}$ ◆

(c) $\mathbf{6}\ \text{m}/\boldsymbol{s} = \mathbf{6}\ \text{m/s} \times \dfrac{1000\ \text{mm}}{1\text{m}} \times \dfrac{3600\ \text{s}}{1\text{m}} = \mathbf{2.16} \times \mathbf{10^7}\text{mm/h}$ ◆

(d) $\mathbf{500}\ \text{g/mm} = 500\ \text{g/mm} \times \dfrac{1\ \text{kg}}{1000\ \text{g}} \times \dfrac{1000\ \text{mm}}{1\text{m}} = 500\ \text{g/m}$ ◄

1.4

$$\text{I} = \mathbf{1035285.8}\ \text{g}\cdot\text{mm}^2 \times \frac{1\ \text{kg}}{(1000\ \text{g})} \times \frac{1\text{m}^2}{(1000\ \text{mm})^2} = \mathbf{1.0352858} \times \mathbf{10^{-3}}\text{kg}\cdot\text{m}^2$$

Rounding off to four significant digits

$$\therefore \text{I} = \mathbf{1.035} \times \mathbf{10^{-3}}\text{kg}\cdot\text{m}^2$$ ◆

1.5

$$\text{I} = \mathbf{1.35285.8} \times \frac{\text{kg}}{(1000\ \text{g})} \times \frac{\text{m}^2}{(1000\ \text{mm})^2} = \mathbf{103.5} \times \mathbf{10^{-5}}\text{kg}\cdot\text{m}^2$$ ◆

1.6

The dimensions of $\frac{gkx}{W}$ are: $[g][k][x]\left[\frac{1}{W}\right] = \left[\frac{L}{T^2}\right][MT^{-2}][L]\left[\frac{1}{MLT^{-2}}\right] = \left[\frac{L}{T^2}\right] = [a]$ Q.E.D.

1.7

The dimensions of $k = \frac{F}{x}$ are: $[k] = \left[\frac{F}{x}\right] = \left[\frac{ML}{T^2}\right]\left[\frac{1}{L}\right] = \left[\frac{M}{T^2}\right]$ ♦

1.8

(a) $25\ \text{mm}/\mu\text{s} = \frac{25\ \text{mm}}{\mu\text{s}} \times \frac{1.0\ \text{m}}{1000\ \text{mm}} \times \frac{1.0\ \mu\text{s}}{10^{-6}\ \text{s}} = 25\ 000\ \text{m/s}$ ◄

1.9

$y = kx^2$ (where $k = 1.0$)

The dimensions of $k = \frac{y}{x^2}$ are: $\therefore\ [k] = \left[\frac{y}{x^2}\right] = \left[\frac{L}{L^2}\right] = \left[\frac{1}{L}\right]$

$y = x^2$ can be dimensionally correct if the units of the constant 1.0 (not shown explicity) are understood to be m^{-1}

1.10

$[I] = \left[mR^2\right] = \left[ML^2\right]$ ♦

1.11

(a) The dimensions of $x = At^2 - Bvt$ are

$$[L] = [A][T^2] - [B][LT^{-1}][T]$$
$$\therefore [A] = [LT^{-2}] \blacktriangleleft \qquad [B] = [1] \text{ (dimensionless)} \blacktriangleleft$$

(b) The dimensions of $x = Avte^{-Bt}$ are

$$[L] = [A][LT^{-1}][T]e^{[B][T]}$$
$$[B][T] = [1] \qquad \therefore [B] = [T^{-1}] \blacktriangleleft$$
$$[L] = [A][LT^{-1}][T] \qquad \therefore [A] = [1] \blacktriangleleft$$

1.12

$\left[m\frac{d^2x}{dt^2}\right] = [m]\left[\frac{L}{T^2}\right] = [MLT^{-2}]$ Therefore, the dimension of each term is $[MLT^{-2}]$

$$\left[c\frac{dx}{dt}\right] = [c]\left[\frac{L}{T}\right] = [MLT^{-2}] \qquad \therefore [c] = [MT^{-1}] \blacklozenge$$

$$[kx] = [k][L] = [MLT^{-2}] \qquad \therefore [k] = [MT^{-2}] \blacklozenge$$

$$\left[P_0 \sin \omega t\right] = \left[P_0\right]\left[\sin \omega t\right] = [MLT^{-2}]$$

$$\therefore \left[P_0\right] = [MLT^{-2}] \blacklozenge$$

$$\left[\omega t\right] = [\omega][T] = [1] \qquad \therefore [\omega] = \left[T^{-1}\right] \blacklozenge$$

1.13

From Eq. (11.17): $G = \frac{FR^2}{m_A m_B}$ which gives $[G] = \frac{[F][R^2]}{[m_A][m_B]}$ (1)

Dim $R^2 = [L^2]$ (2)

◆

For an absolute system of units: Dimension $F = \left[\frac{ML}{T^2}\right]$ and $[m] = [M]$

From Eqs. (1) and (2), we obtain $[G] = \left[\frac{ML}{T^2}\right]\left[\frac{[L^2]}{[M][M]}\right] = \left[M^{-1}L^3T^{-2}\right]$ ◆

1.14

$$120 \text{ hp} = 120 \text{ hp} \times \frac{0.7457 \text{ kW}}{1.0 \text{ hp}} = 89.5 \text{ kW} ◄$$

1.15

$$F = G\frac{m_A m_B}{R^2} = \left(6.67 \times 10^{-11}\right)\frac{(10)(10)}{(0.5)^2} = 2.668 \times 10^{-8} \text{ N}$$

$$W = mg = (10)(9.81) = 98.1 \text{ N}$$

$$\% \text{ of weight} = \frac{F}{W} \times 100\% = \frac{2.668 \times 10^{-8}}{98.1} \times 100\% = 2.72 \times 10^{-8}\%$$ ◆

1.16

$$F = G\frac{m_A m_B}{R^2} = (6.67\times 10^{-11})\times\frac{(2)(2)}{\left(\frac{160}{1000}\right)^2} = 1.042\times 10^{-8}\,\text{N} \quad \blacklozenge$$

1.17

$$h = 9000\text{ m} = 9\text{ km}$$

On earth: $W_e = \dfrac{GM_e m}{R_e^2}$ At elevation h: $W = \dfrac{GM_e m}{(R_e+h)^2}$

$$W = W_e\frac{R_e^2}{(R_e+h)^2} = 900\frac{6378^2}{(6378+9)^2} = 897.5\text{ N} \quad \blacktriangleright$$

1.18

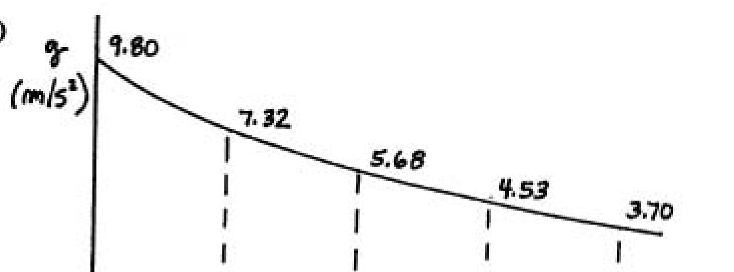
$$g_m = \frac{GM_m}{R_m^2} \qquad g_e = \frac{GM_e}{R_e^2}$$

$$\frac{g_m}{g_e} = \frac{M_m R_e^2}{M_e R_m^2} = \frac{0.07348(6378)^2}{5.974(1737)^2} = 0.1658 \approx \frac{1}{6}\text{ Q.E.D.}$$

1.19

Shown below is the plot of $g = \dfrac{GM_e}{R^2} = \dfrac{(6.67\times 10^{-11})(5.9742\times 10^{24})}{(6378+h)^2\,(10^6)}$

h (km)	g (m/s^2)
0	9.80
1000	7.32
2000	5.68
3000	4.53
4000	3.70



1.20

On earth: $W_e = \dfrac{GM_e m}{R_e^2}$ At elevation h: $W = \dfrac{GM_e m}{(R_e+h)^2}$

$$W = \frac{W_e}{10} \qquad \frac{GM_e m}{(R_e + h)^2} = \frac{GM_e m}{10R_e^2} \qquad (R_e + h)^2 = 10R_e^2$$

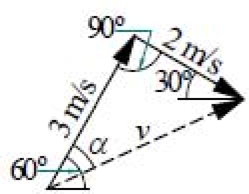
$$(6378 + h)^2 = 10(6378)^2 \qquad h = 13\ 790\ \text{km} \blacktriangleleft$$

1.21

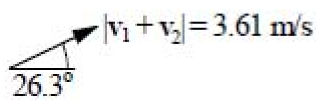
$$\begin{aligned} R &= R_e + R_m + d = 6378 + 1737 + 384 \times 10^3 \\ &= 392.1 \times 10^3\ \text{km} = 392.1 \times 10^6\ \text{m} \end{aligned}$$

$$\begin{aligned} F &= G\frac{M_e M_m}{R^2} = \left(6.67 \times 10^{-11}\right) \frac{\left(5.974 \times 10^{24}\right)\left(0.07348 \times 10^{24}\right)}{\left(392.1 \times 10^6\right)^2} \\ &= 1.904 \times 10^{20}\ \text{N} \blacktriangleleft \end{aligned}$$

1.22



$$v = \sqrt{3^2 + 2^2} = 3.61\ \text{m/s} \qquad \alpha = \tan^{-1}\frac{2}{3} = 33.7^\circ$$



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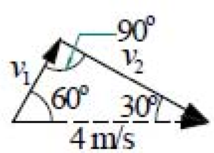
1.23

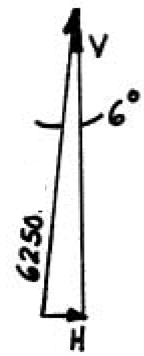


$$v_1 = 4\sin 30^\circ = 2\ \text{m/s} \blacktriangleleft \qquad v_2 = 4\sin 60^\circ = 3.46\ \text{m/s} \blacktriangleleft$$

1.24

Horizontal: $H = 6250 \sin 6^\circ = 653$ N (→) ◆

Vertical: $V = 6250 \cos 6^\circ = 6220$ N (↑) ◆



1.25

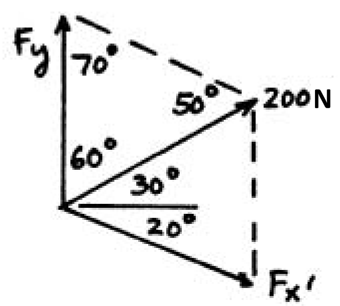
(a) $F_x = 200 \cos 30^\circ = \underrightarrow{173.2}$ N ◆ $F_y = 200 \sin 30^\circ = 100.0$ N ↑ ◆

(b) Law of sines: $\dfrac{200}{\sin 70^\circ} = \dfrac{F_y}{\sin 50^\circ} = \dfrac{F_{x'}}{\sin 60^\circ}$

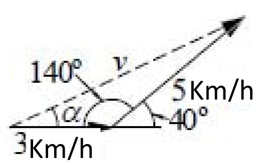
which gives

$$F_y = \frac{200 \sin 50^\circ}{\sin 70^\circ} = 163.0 \text{ N}$$ ◆

$$F_{x'} = \frac{200 \sin 60^\circ}{\sin 70^\circ} = 184.3 \text{ N}$$ ◆



1.26



Law of cosines: $v = \sqrt{3^2 + 5^2 - 2(3)(5)\cos 140^\circ} = 7.549$ Km/h

Law of sines: $\dfrac{5}{\sin \alpha} = \dfrac{7.549}{\sin 140^\circ}$ $\sin \alpha = 0.4257$ $\alpha = 25.2^\circ$

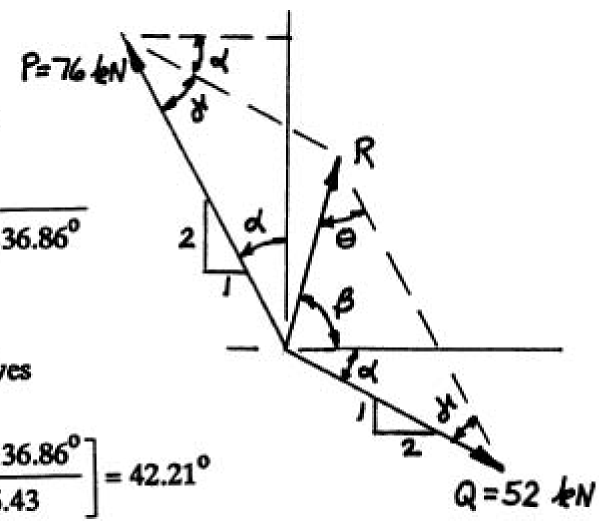
◄

1.27

Geometry: $\alpha = \tan^{-1} 0.5 = 26.57^\circ$

$2\alpha + \gamma = 90^\circ$ from which

$\gamma = 90^\circ - 2(26.57^\circ) = 36.86^\circ$



Law of cosines:

$$R = \sqrt{76^2 + 52^2 - 2(76)(52)\cos 36.86^\circ}$$

$$\therefore\ R = 46.43\ \text{kN}$$

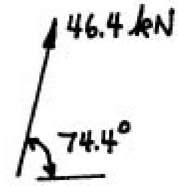
Law of sines: $\dfrac{R}{\sin\gamma} = \dfrac{Q}{\sin\theta}$ which gives

$$\theta = \sin^{-1}\left[\frac{Q\sin\gamma}{R}\right] = \sin^{-1}\left[\frac{52\sin 36.86^\circ}{46.43}\right] = 42.21^\circ$$

Geometry: $\beta = 180^\circ - \theta - \gamma - \alpha$

$$= 180^\circ - 42.21^\circ - 36.86^\circ - 26.57^\circ = 74.4^\circ$$

Therefore, the resultant of P and Q is:



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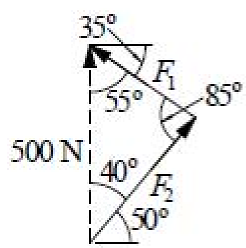
1.28

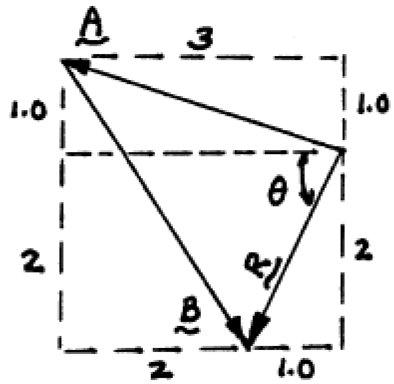


Law of sines: $\dfrac{500}{\sin 85^\circ} = \dfrac{F_1}{\sin 40^\circ} = \dfrac{F_2}{\sin 55^\circ}$

$$\therefore F_1 = \frac{500\sin 40^\circ}{\sin 85^\circ} = 323\ \text{N} \blacktriangleleft$$

$$F_2 = \frac{500\sin 55^\circ}{\sin 85^\circ} = 411\ \text{N} \blacktriangleleft$$

1.29

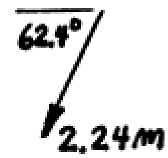


$\mathbf{R} = \mathbf{A} + \mathbf{B}$

By inspection of the triangle (dimensions in meters

$R = \sqrt{2^2 + 1.0^2} = 2.24$ m and $\theta = \tan^{-1} 2 = 62.4$

Therefore, the resultant of **A** and **B** is:



◆

1.30

$\mathbf{R} = \mathbf{P} + \mathbf{Q}$

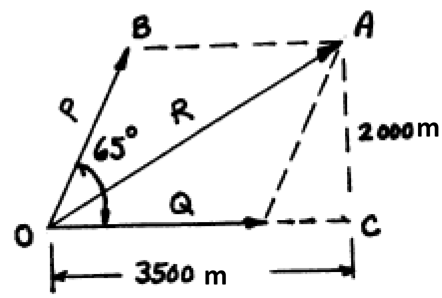
$$P = \frac{2000}{\sin 65^o} = 2207\,\text{m}$$

$$Q = 3500 - P\cos 65^o$$

$$= 3500 - 2207\cos 65^o = 2567 \text{ m}$$

Therefore, the components are:

2210 ft along OB and 2570m along OC ◆



1.31

Law of sines: $\dfrac{360}{\sin 95^o} = \dfrac{P_{AB}}{\sin 30^o} = \dfrac{P_{AC}}{\sin 55^o}$

which gives

$$P_{AB} = \frac{360\sin 30^o}{\sin 95^o} = 180.7\,\text{N}$$ ◆

$$P_{AC} = \frac{360\sin 55^o}{\sin 95^o} = 296\,\text{N}$$ ◆