Problem 1-1

Represent each of the following combinations of units in the correct SI form using an appropriate prefix:
(a) m/ms **(b)** μkm **(c)** ks/mg **(d)** $\mathrm{km}\cdot\mu\mathrm{N}$

Units Used:

$\mu\mathrm{N} = 10^{-6}\ \mathrm{N}$

$\mu\mathrm{km} = 10^{-6}\ \mathrm{km}$

$\mathrm{Gs} = 10^{9}\ \mathrm{s}$

$\mathrm{ks} = 10^{3}\ \mathrm{s}$

$\mathrm{mN} = 10^{-3}\ \mathrm{N}$

$\mathrm{ms} = 10^{-3}\ \mathrm{s}$

Solution:

(a) $\dfrac{\mathrm{m}}{\mathrm{ms}} = 1\times 10^{3}\,\dfrac{\mathrm{m}}{\mathrm{s}}$

$$\frac{\mathrm{m}}{\mathrm{ms}} = 1\,\frac{\mathrm{km}}{\mathrm{s}}$$

(b) $\mu\mathrm{km} = 1\times 10^{-3}\,\mathrm{m}$

$$\mu\mathrm{km} = 1\,\mathrm{mm}$$

(c) $\dfrac{\mathrm{ks}}{\mathrm{mg}} = 1\times 10^{9}\,\dfrac{\mathrm{s}}{\mathrm{kg}}$

$$\frac{\mathrm{ks}}{\mathrm{mg}} = 1\,\frac{\mathrm{Gs}}{\mathrm{kg}}$$

(d) $\mathrm{km}\cdot\mu\mathrm{N} = 1\times 10^{-3}\,\mathrm{m\,N}$

$$\mathrm{km}\cdot\mu\mathrm{N} = 1\,\mathrm{mm}\cdot\mathrm{N}$$

Problem 1-2

Wood has a density *d*. What is its density expressed in SI units?

Units Used:

$Mg = 1000\ kg$

Given:

$d = 4.70\ \frac{slug}{ft^3}$

Solution:

$1slug = 14.594\ kg$

$d = 2.42\ \frac{Mg}{m^3}$

Problem 1-3

Represent each of the following combinations of units in the correct SI form using an appropriate prefix:

(a) Mg/mm **(b)** mN/μs **(c)** $\mu m \cdot Mg$

Solution:

(a) $\frac{Mg}{mm} = \frac{10^3\ kg}{10^{-3}\ m} = \frac{10^6\ kg}{m} = \frac{Gg}{m}$

$\frac{Mg}{mm} = \frac{Gg}{m}$

(b) $\frac{mN}{\mu s} = \frac{10^{-3}\ N}{10^{-6}\ s} = \frac{10^3\ N}{s} = \frac{kN}{s}$

$\frac{mN}{\mu s} = \frac{kN}{s}$

(c) $\mu m \cdot Mg = \left(10^{-6}\ m\right)\left(10^3\ kg\right) = 10^{-3}\ m \cdot kg$

$\mu m \cdot Mg = mm \cdot kg$

Problem 1-4

Represent each of the following combinations of units in the correct SI form: **(a)** Mg/ms, **(b)** N/mm, **(c)** mN/(kg·μs).

Solution:

(a) $\frac{\text{Mg}}{\text{ms}} = \frac{10^3\ \text{kg}}{10^{-3}\ \text{s}} = \frac{10^6\ \text{kg}}{\text{s}} = \frac{\text{Gg}}{\text{s}}$

$$\frac{\text{Mg}}{\text{ms}} = \frac{\text{Gg}}{\text{s}}$$

(b) $\frac{\text{N}}{\text{mm}} = \frac{1\ \text{N}}{10^{-3}\ \text{m}} = 10^3\,\frac{\text{N}}{\text{m}} = \frac{\text{kN}}{\text{m}}$

$$\frac{\text{N}}{\text{mm}} = \frac{\text{kN}}{\text{m}}$$

(c) $\frac{\text{mN}}{\text{kg}\cdot\mu\text{s}} = \frac{10^{-3}\ \text{N}}{10^{-6}\ \text{kg}\cdot\text{s}} = \frac{\text{kN}}{\text{kg}\cdot\text{s}}$

$$\frac{\text{mN}}{\text{kg}\cdot\mu\text{s}} = \frac{\text{kN}}{\text{kg}\cdot\text{s}}$$

Problem 1-5

Represent each of the following with SI units having an appropriate prefix: **(a)** S_1, **(b)** S_2, **(c)** S_3.

Units Used:

$\text{kg} = 1000\ \text{g} \qquad \text{ms} = 10^{-3}\ \text{s} \qquad \text{kN} = 10^3\ \text{N}$

Given:

$S_1 = 8653\ \text{ms}$

$S_2 = 8368\ \text{N}$

$S_3 = 0.893\ \text{kg}$

Solution:

(a) $S_1 = 8.653\ \text{s}$

(b) $S_2 = 8.368\,\text{kN}$

(c) $S_3 = 893\,\text{g}$

Problem 1-6

Represent each of the following to three significant figures and express each answer in SI units using an appropriate prefix: **(a)** x, **(b)** y, and **(c)** z.

Units Used:

$\text{MN} = 10^6\ \text{N}$

$\mu\text{g} = 1 \times 10^{-6}\ \text{gm}$

$\text{kN} = 10^3\ \text{N}$

Given:

$x = 45320\ \text{kN}$

$y = \left(568 \times 10^5\right)\ \text{mm}$

$z = 0.00563\ \text{mg}$

Solution:

(a) $x = 45.3\,\text{MN}$

(b) $y = 56.8\,\text{km}$

(c) $z = 5.63\,\mu\text{g}$

Problem 1-7

Evaluate $(a \cdot b)/c$ to three significant figures and express the answer in SI units using an appropriate prefix.

Units Used:

$\mu\text{m} = 10^{-6}\ \text{m}$

Given:

$a = (204\ \text{mm})$

$b = (0.00457\ \text{kg})$

$c = (34.6\ \text{N})$

Solution:

$$l = \frac{a\,b}{c} \qquad l = 26.945\,\frac{\mu\text{m}\cdot\text{kg}}{\text{N}}$$

Problem 1-8

If a car is traveling at speed v, determine its speed in kilometers per hour and meters per second.

Given:

$$v = 55\,\frac{\text{mi}}{\text{hr}}$$

Solution:

$$v = 88.514\,\frac{\text{km}}{\text{hr}}$$

$$v = 24.6\,\frac{\text{m}}{\text{s}}$$

Problem 1-9

Convert: (a) S_1 to $\text{N}\cdot\text{m}$, (b) S_2 to kN/m^3, (c) S_3 to mm/s. Express the result to three significant figures. Use an appropriate prefix.

Units Used:

$$\text{kN} = 10^3\ \text{N}$$

Given:

$$S_1 = 200g\ \text{lb}\cdot\text{ft}$$

$$S_2 = 350g\,\frac{\text{lb}}{\text{ft}^3}$$

$$S_3 = 8\,\frac{\text{ft}}{\text{hr}}$$

Solution:

(a) $S_1 = 271\,\mathrm{N\cdot m}$

(b) $S_2 = 55.0\,\frac{\mathrm{kN}}{\mathrm{m}^3}$

(c) $S_3 = 0.677\,\frac{\mathrm{mm}}{\mathrm{s}}$

Problem 1-10

What is the weight in newtons of an object that has a mass of: (a) m_1, (b) m_2, (c) m_3? Express the result to three significant figures. Use an appropriate prefix.

Units Used:

$\mathrm{Mg} = 10^3\ \mathrm{kg}$

$\mathrm{mN} = 10^{-3}\ \mathrm{N}$

$\mathrm{kN} = 10^3\ \mathrm{N}$

Given:

$m_1 = 10\ \mathrm{kg}$

$m_2 = 0.5\ \mathrm{gm}$

$m_3 = 4.50\ \mathrm{Mg}$

Solution:

(a) $W = m_1 g$

$W = 98.1\ \mathrm{N}$

(b) $W = m_2 g$

$W = 4.90\,\mathrm{mN}$

(c) $W = m_3 g$

$W = 44.1\ \mathrm{kN}$

Problem 1-11

If an object has mass *m*, determine its mass in kilograms.

Given:

$m = 40 \text{ slug}$

Solution:

$m = 584 \text{ kg}$

Problem 1-12

The specific weight (wt./vol.) of brass is ρ. Determine its density (mass/vol.) in SI units. Use an appropriate prefix.

Units Used:

$\text{Mg} = 10^3 \text{ kg}$

Given:

$\rho = 520 \dfrac{\text{lb}}{\text{ft}^3}$

Solution:

$\rho = 8.33 \dfrac{\text{Mg}}{\text{m}^3}$

Problem 1-13

A concrete column has diameter *d* and length *L*. If the density (mass/volume) of concrete is ρ, determine the weight of the column in pounds.

Units Used:

$\text{Mg} = 10^3 \text{ kg}$

$\text{kip} = 10^3 \text{ lb}$

Given:

$d = 350 \text{ mm}$

$L = 2 \text{ m}$

$\rho = 2.45 \frac{\text{Mg}}{\text{m}^3}$

Solution:

$V = \pi \left(\frac{d}{2}\right)^2 L \qquad V = 192.423 \text{ L}$

$W = \rho V \qquad W = 1.04 \text{ kip}$

Problem 1-14

The density (mass/volume) of aluminum is ρ. Determine its density in SI units. Use an appropriate prefix.

Units Used:

$\text{Mg} = 1000 \text{ kg}$

Given:

$\rho = 5.26 \frac{\text{slug}}{\text{ft}^3}$

Solution:

$\rho = 2.17 \frac{\text{Mg}}{\text{m}^3}$

Problem 1-15

Determine your own mass in kilograms, your weight in newtons, and your height in meters.

Solution:

Example

$W = 150 \text{ lb}$

$m = W \qquad m = 68.039 \text{ kg}$

$Wg = 667.233 \text{ N}$

$h = 72 \text{ in} \qquad h = 1.829 \text{ m}$

Problem 1-16

Two particles have masses m_1 and m_2, respectively. If they are a distance d apart, determine the force of gravity acting between them. Compare this result with the weight of each particle.

Units Used:

$$G = 66.73 \times 10^{-12} \frac{\text{m}^3}{\text{kg}\cdot\text{s}^2}$$

$$\text{nN} = 10^{-9}\ \text{N}$$

Given:

$m_1 = 8$ kg

$m_2 = 12$ kg

$d = 800$ mm

Solution:

$$F = \frac{G\, m_1\, m_2}{d^2}$$

$F = 10.0$ nN

$W_1 = m_1\, g \qquad W_1 = 78.5\ \text{N} \qquad \frac{W_1}{F} = 7.85 \times 10^9$

$W_2 = m_2\, g \qquad W_2 = 118\ \text{N} \qquad \frac{W_2}{F} = 1.18 \times 10^{10}$

Problem 1-17

Using the base units of the SI system, show that $F = G(m_1 m_2)/r^2$ is a dimensionally homogeneous equation which gives F in newtons. Compute the gravitational force acting between two identical spheres that are touching each other. The mass of each sphere is m_1, and the radius is r.

Units Used:

$$\mu\text{N} = 10^{-6}\ \text{N} \qquad G = 66.73\ 10^{-12} \frac{\text{m}^3}{\text{kg}\cdot\text{s}^2}$$

Given:

$m_1 = 150 \text{ kg}$

$r = 275 \text{ mm}$

Solution:

$$F = \frac{G\, m_1^2}{(2r)^2}$$

$F = 4.96 \ \mu\text{N}$

Since the force F is measured in Newtons, then the equation is dimensionally homogeneous.

Problem 1-18

Evaluate each of the following to three significant figures and express each answer in SI units using an appropriate prefix: (a) x, (b) y, (c) z.

Units Used:

$\text{MN} = 10^6 \text{ N}$

$\text{kN} = 10^3 \text{ N}$

$\mu\text{m} = 10^{-6} \text{ m}$

Given:

$x = (200 \text{ kN})^2$

$y = (0.005 \text{ mm})^2$

$z = (400 \text{ m})^3$

Solution:

(a) $x = 0.040 \text{ MN}^2$

(b) $y = 25.0 \ \mu\text{m}^2$

(c) $z = 0.0640 \text{ km}^3$

Problem 1-19

Evaluate each of the following to three significant figures and express each answer in SI units using an appropriate prefix: (a) a_1/b_1, (b) a_2b_2/c_2, (c) a_3b_3.

Units Used:

$\mu m = 10^{-6}\ m \qquad Mm = 10^{6}\ m$

$Mg = 10^{6}\ gm \qquad kg = 10^{3}\ gm$

$ms = 10^{-3}\ s$

Given:

$a_1 = 684\ \mu m$

$b_1 = 43\ ms$

$a_2 = 28\ ms$

$b_2 = 0.0458\ Mm$

$c_2 = 348\ mg$

$a_3 = 2.68\ mm$

$b_3 = 426\ Mg$

Solution:

(a) $\dfrac{a_1}{b_1} = 15.9\,\dfrac{mm}{s}$

(b) $\dfrac{a_2\ b_2}{c_2} = 3.69\,Mm\ \dfrac{s}{kg}$

(c) $a_3\ b_3 = 1.14\,km\cdot kg$

Problem 1-20

Evaluate each of the following to three significant figures and express each answer in SI units using an appropriate prefix: **(a)** $a_1/b_1^{\,2}$ **(b)** $a_2^{\,2}b_2^{\,3}$.

Units Used:

$Mm = 10^{6}\ m$

Given:

$a_1 = 0.631\ \text{Mm}$

$b_1 = 8.60\ \text{kg}$

$a_2 = 35\ \text{mm}$

$b_2 = 48\ \text{kg}$

Solution:

(a) $\dfrac{a_1}{{b_1}^2} = 8.532\,\dfrac{\text{km}}{\text{kg}^2}$

(b) ${a_2}^2\ {b_2}^3 = 135.48\,\text{kg}^3\cdot\text{m}^2$

Problem 2-1

Determine the magnitude of the resultant force $\mathbf{F_R = F_1 + F_2}$ and its direction, measured counterclockwise from the positive *x* axis.

Given:

$F_1 = 600$ N

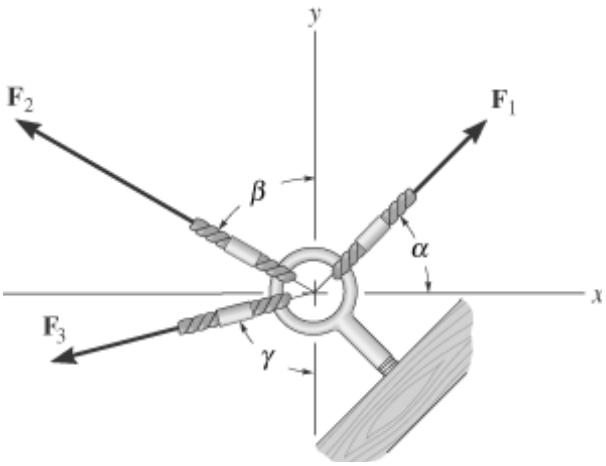
$F_2 = 800$ N

$F_3 = 450$ N

$\alpha = 45$ deg

$\beta = 60$ deg

$\gamma = 75$ deg



Solution:

$\psi = 90 \text{ deg} - \beta + \alpha$

$F_R = \sqrt{F_1^2 + F_2^2 - 2\, F_1\, F_2 \cos(\psi)}$

$F_R = 867$ N

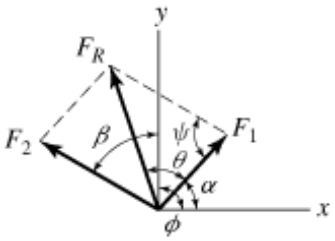
$\dfrac{F_R}{\sin(\psi)} = \dfrac{F_2}{\sin(\theta)}$

$\theta = \operatorname{asin}\left(F_2 \dfrac{\sin(\psi)}{F_R}\right)$

$\theta = 63.05 \text{ deg}$

$\phi = \theta + \alpha$

$\phi = 108 \text{ deg}$



Problem 2-2

Determine the magnitude of the resultant force and its direction measured counterclockwise from the positive *x* axis.

Given:

$F_1 = 80$ lb

$F_2 = 60$ lb

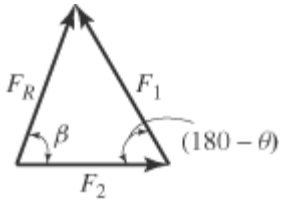
$\theta = 120 \text{ deg}$

Solution:

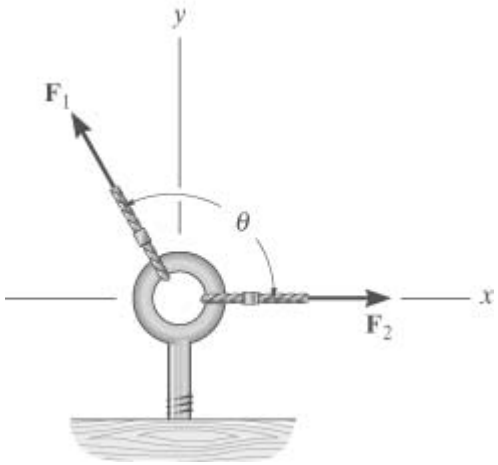
$$F_R = \sqrt{F_1^2 + F_2^2 - 2\,F_1\,F_2\cos(180 \text{ deg} - \theta)}$$

$F_R = 72.1 \text{ lb}$

$$\beta = \operatorname{asin}\left(F_1\,\frac{\sin(180 \text{ deg} - \theta)}{F_R}\right)$$



$\beta = 73.9 \text{ deg}$



Problem 2-3

Determine the magnitude of the resultant force $\mathbf{F_R} = \mathbf{F_1} + \mathbf{F_2}$ and its direction, measured counterclockwise from the positive *x* axis.

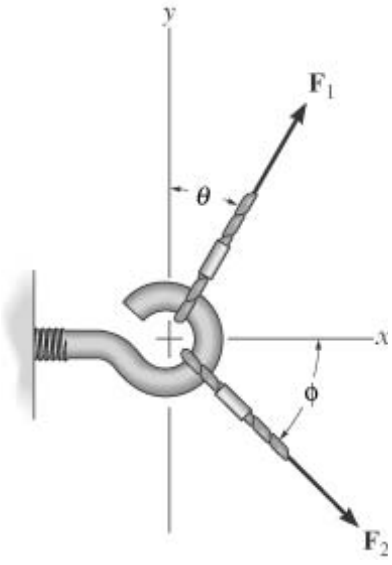
Given:

$F_1 = 250 \text{ lb}$

$F_2 = 375 \text{ lb}$

$\theta = 30 \text{ deg}$

$\phi = 45 \text{ deg}$



Solution:

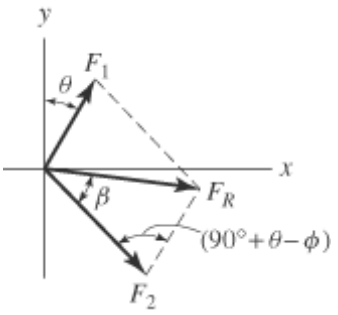
$$F_R = \sqrt{F_1^2 + F_2^2 - 2\,F_1\,F_2\cos(90 \text{ deg} + \theta - \phi)}$$

$F_R = 178 \text{ kg}$

$$\frac{F_R}{\sin(90 \text{ deg} + \theta - \phi)} = \frac{F_1}{\sin(\beta)}$$

$$\beta = \operatorname{asin}\left(\frac{F_1}{F_R}\,\sin(90 \text{ deg} + \theta - \phi)\right)$$

$\beta = 37.89 \text{ deg}$



Angle measured ccw from *x* axis

$360\ \text{deg} - \phi + \beta = 353\,\text{deg}$

Problem 2-4

Determine the magnitude of the resultant force $\mathbf{F_R} = \mathbf{F_1} + \mathbf{F_2}$ and its direction, measured counterclockwise from the positive *u* axis.

Given:

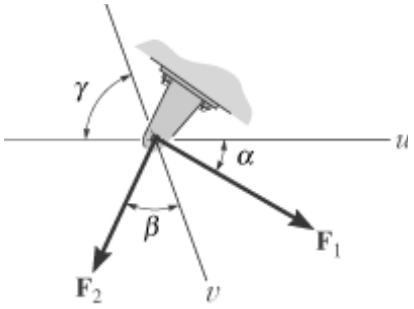
$F_1 = 300\ \text{N}$

$F_2 = 500\ \text{N}$

$\alpha = 30\ \text{deg}$

$\beta = 45\ \text{deg}$

$\gamma = 70\ \text{deg}$



Solution:

$$F_R = \sqrt{F_1^2 + F_2^2 - 2\,F_1\,F_2\cos(180\ \text{deg} - \beta - \gamma + \alpha)}$$

$F_R = 605\ \text{N}$

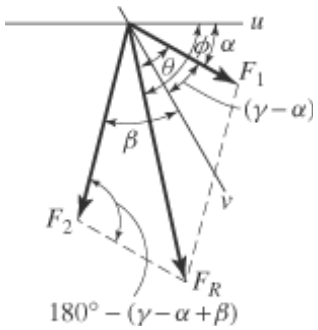
$$\frac{F_R}{\sin(180\ \text{deg} - \beta - \gamma + \alpha)} = \frac{F_2}{\sin(\theta)}$$

$$\theta = \text{asin}\left(F_2\,\frac{\sin(180\ \text{deg} - \beta - \gamma + \alpha)}{F_R}\right)$$

$\theta = 55.40\,\text{deg}$

$\phi = \theta + \alpha$

$\phi = 85.4\,\text{deg}$



Problem 2-5

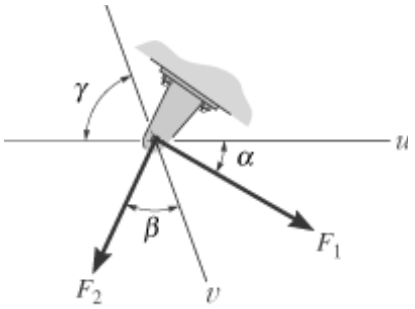
Resolve the force $\mathbf{F_1}$ into components acting along the *u* and *v* axes and determine the magnitudes of the components.

Given:

$F_1 = 300\ \text{N} \qquad \alpha = 30\ \text{deg}$

$F_2 = 500\ \text{N} \quad \beta = 45\ \text{deg}$

$\gamma = 70\ \text{deg}$



Solution:

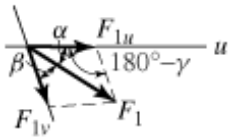
$$\frac{F_{1u}}{\sin(\gamma - \alpha)} = \frac{F_1}{\sin(180\ \text{deg} - \gamma)}$$

$$F_{1u} = F_1 \frac{\sin(\gamma - \alpha)}{\sin(180\ \text{deg} - \gamma)}$$

$F_{1u} = 205\ \text{N}$

$$\frac{F_{1v}}{\sin(\alpha)} = \frac{F_1}{\sin(180\ \text{deg} - \gamma)}$$

$$F_{1v} = F_1 \frac{\sin(\alpha)}{\sin(180\ \text{deg} - \gamma)}$$



$F_{1v} = 160\ \text{N}$

Problem 2-6

Resolve the force $\mathbf{F_2}$ into components acting along the *u* and *v* axes and determine the magnitudes of the components.

Given:

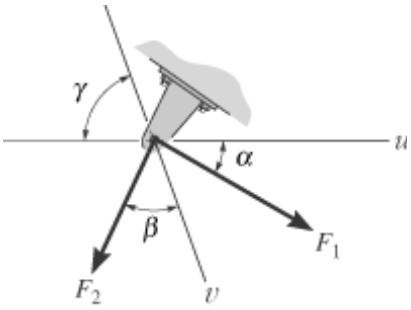
$F_1 = 300\ \text{N}$

$F_2 = 500\ \text{N}$

$\alpha = 30\ \text{deg}$

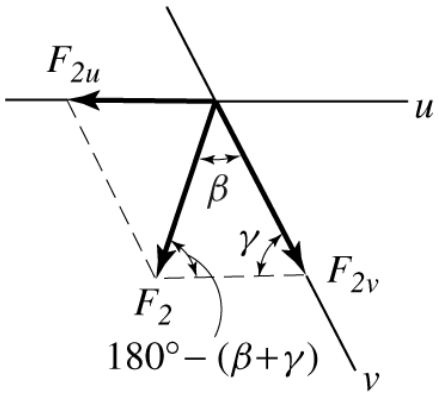
$\beta = 45\ \text{deg}$

$\gamma = 70\ \text{deg}$



Solution:

$$F_{2u} = F_2\left(\frac{\sin(\beta)}{\sin(\gamma)}\right)$$



$F_{2u} = 376.2\ \text{N}$

$$F_{2v} = F_2\left[\frac{\sin\left[180\ \text{deg} - (\beta + \gamma)\right]}{\sin(\gamma)}\right]$$

$F_{2v} = 482.2\ \text{N}$

Problem 2-7

Determine the magnitude of the resultant force $\mathbf{F_R = F_1 + F_2}$ and its direction measured counterclockwise from the positive *u* axis.

Given:

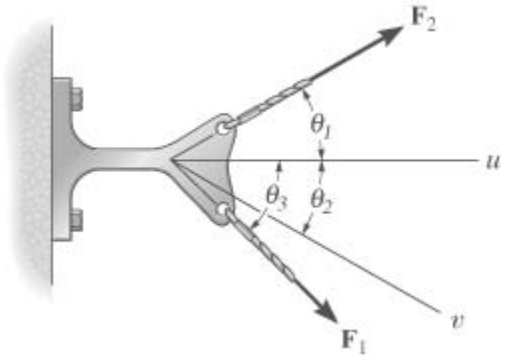
$F_1 = 25\ \text{lb}$

$F_2 = 50\ \text{lb}$

$\theta_1 = 30\ \text{deg}$

$\theta_2 = 30\ \text{deg}$

$\theta_3 = 45\ \text{deg}$



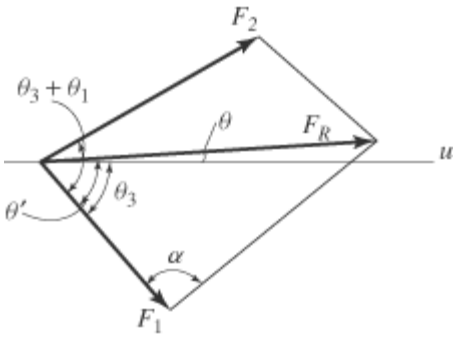
Solution:

$\alpha = 180\ \text{deg} - (\theta_3 + \theta_1)$

$$F_R = \sqrt{F_2^2 + F_1^2 - 2\,F_1\,F_2\cos(\alpha)}$$

$F_R = 61.4\,\text{lb}$

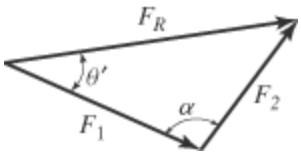
$$\frac{\sin(\theta')}{F_2} = \frac{\sin(\alpha)}{F_R} \qquad \theta' = \text{asin}\left(\sin(\alpha)\,\frac{F_2}{F_R}\right)$$



$\theta' = 51.8\,\text{deg}$

$\theta = \theta' - \theta_3$

$\theta = 6.8\,\text{deg}$



Problem 2-8

Resolve the force $\mathbf{F_1}$ into components acting along the *u* and *v* axes and determine the components.

Given:

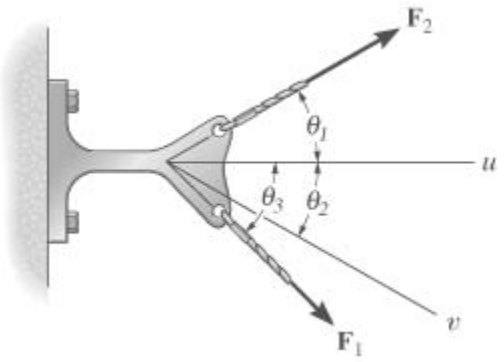
$F_1 = 25$ lb

$F_2 = 50$ lb

$\theta_1 = 30$ deg

$\theta_2 = 30$ deg

$\theta_3 = 45$ deg

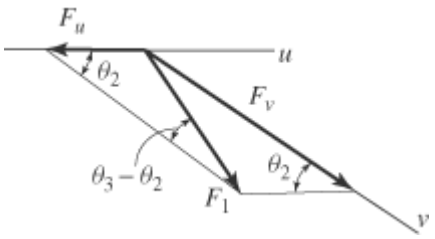


Solution:

$$\frac{-F_u}{\sin(\theta_3 - \theta_2)} = \frac{F_1}{\sin(\theta_2)}$$

$$F_u = \frac{-F_1 \sin(\theta_3 - \theta_2)}{\sin(\theta_2)}$$

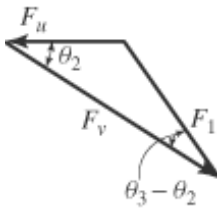
$F_u = -12.9$ lb



$$\frac{F_v}{\sin(180 \text{ deg} - \theta_3)} = \frac{F_1}{\sin(\theta_2)}$$

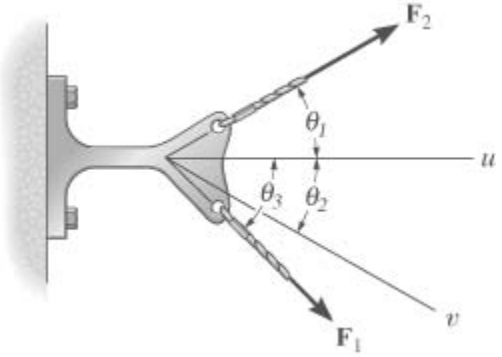
$$F_v = \frac{F_1 \sin(180 \text{ deg} - \theta_3)}{\sin(\theta_2)}$$

$F_v = 35.4$ lb



Problem 2-9

Resolve the force $\mathbf{F_2}$ into components acting along the *u* and *v* axes and determine the components.



Given:

$F_1 = 25$ lb

$F_2 = 50$ lb

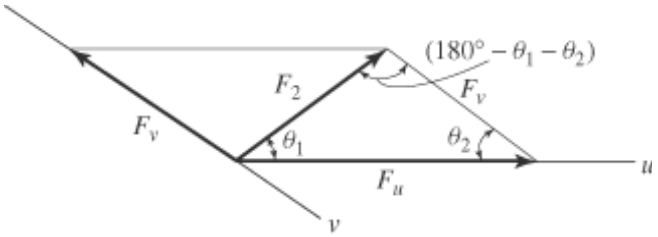
$\theta_1 = 30$ deg

$\theta_2 = 30 \text{ deg}$

$\theta_3 = 45 \text{ deg}$

Solution:

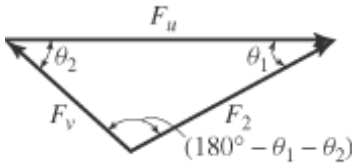
$$\frac{F_u}{\sin\left[180 \text{ deg} - (\theta_1 + \theta_2)\right]} = \frac{F_2}{\sin(\theta_2)}$$



$$F_u = \frac{F_2 \sin\left[180 \text{ deg} - (\theta_1 + \theta_2)\right]}{\sin(\theta_2)}$$

$F_u = 86.6 \text{ lb}$

$$\frac{-F_v}{\sin(\theta_1)} = \frac{F_2}{\sin(\theta_2)}$$



$$F_v = \frac{-F_2 \sin(\theta_1)}{\sin(\theta_2)}$$

$F_v = -50 \text{ lb}$

Problem 2-10

Determine the components of the **F** force acting along the *u* and *v* axes.

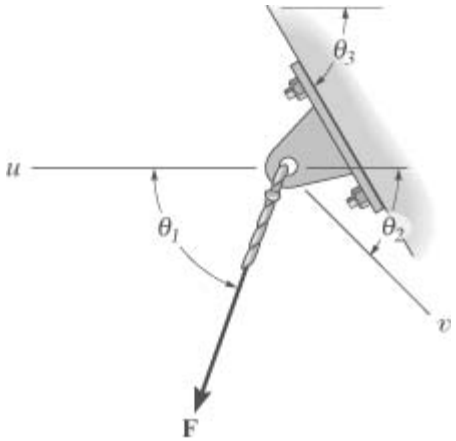
Given:

$\theta_1 = 70 \text{ deg}$

$\theta_2 = 45 \text{ deg}$

$\theta_3 = 60 \text{ deg}$

$F = 250 \text{ N}$

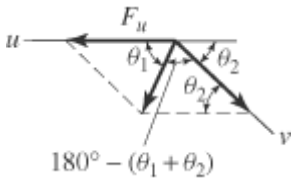


Solution:

$$\frac{F_u}{\sin\left[180 \text{ deg} - (\theta_1 + \theta_2)\right]} = \frac{F}{\sin(\theta_2)}$$

$$F_u = \frac{F \sin\left[180 \text{ deg} - (\theta_1 + \theta_2)\right]}{\sin(\theta_2)} \qquad F_u = 320 \text{ N}$$

$$\frac{F_v}{\sin(\theta_1)} = \frac{F}{\sin(\theta_2)}$$



$$F_v = \frac{F\sin(\theta_1)}{\sin(\theta_2)}$$

$F_v = 332$ N

Problem 2-11

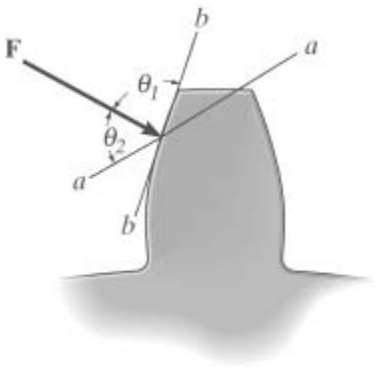
The force **F** acts on the gear tooth**.** Resolve this force into two components acting along the lines *aa* and *bb.*

Given:

$F = 20$ lb

$\theta_1 = 80$ deg

$\theta_2 = 60$ deg

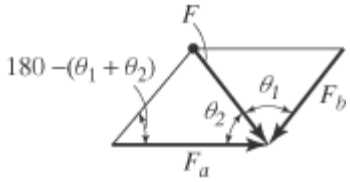


Solution:

$$\frac{F}{\sin\left[180 \text{ deg} - (\theta_1 + \theta_2)\right]} = \frac{F_a}{\sin(\theta_1)}$$

$$F_a = \frac{F\sin(\theta_1)}{\sin\left[180 \text{ deg} - (\theta_1 + \theta_2)\right]}$$

$F_a = 30.6$ lb



$$\frac{F}{\sin\left[180 \text{ deg} - (\theta_1 + \theta_2)\right]} = \frac{F_b}{\sin(\theta_2)}$$

$$F_b = \frac{F\sin(\theta_2)}{\sin\left[180 \text{ deg} - (\theta_1 + \theta_2)\right]}$$

$F_b = 26.9$ lb

Problem 2-12

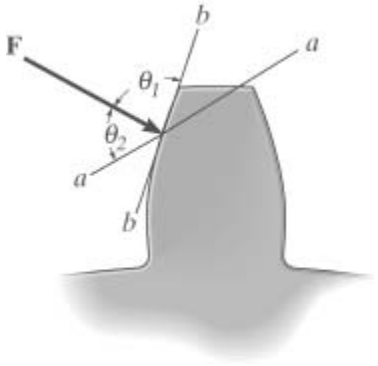
The component of force **F** acting along line *aa* is required to be F_a. Determine the magnitude of **F** and its component along line *bb*.

Given:

$F_a = 30$ lb

$\theta_1 = 80$ deg

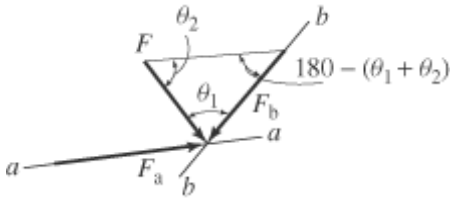
$\theta_2 = 60$ deg



Solution:

$$\frac{F_a}{\sin(\theta_1)} = \frac{F}{\sin[180\ \text{deg} - (\theta_1 + \theta_2)]}$$

$$F = F_a \left(\frac{\sin(180\ \text{deg} - \theta_1 - \theta_2)}{\sin(\theta_1)} \right) \quad F = 19.6\,\text{lb}$$



$$\frac{F_a}{\sin(\theta_1)} = \frac{F_b}{\sin(\theta_2)}$$

$$F_b = \frac{F_a \sin(\theta_2)}{\sin(\theta_1)} \quad F_b = 26.4\,\text{lb}$$

Problem 2-13

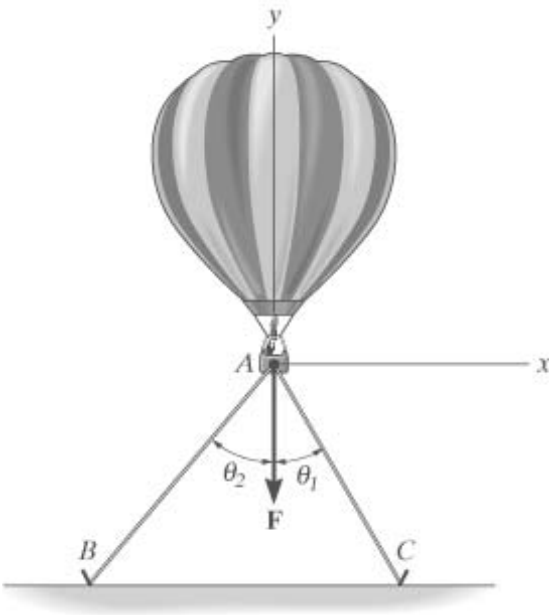
A resultant force **F** is necessary to hold the ballon in place. Resolve this force into components along the tether lines *AB* and *AC*, and compute the magnitude of each component.

Given:

$F = 350$ lb

$\theta_1 = 30$ deg

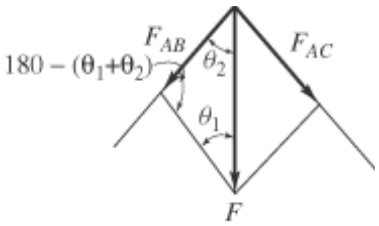
$\theta_2 = 40$ deg

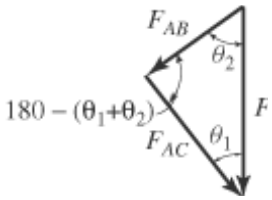


Solution:

$$\frac{F_{AB}}{\sin(\theta_1)} = \frac{F}{\sin[180\ \text{deg} - (\theta_1 + \theta_2)]}$$

$$F_{AB} = F\left[\frac{\sin(\theta_1)}{\sin\left[180\ \text{deg} - (\theta_1 + \theta_2)\right]}\right]$$





$F_{AB} = 186\,\text{lb}$

$$\frac{F_{AC}}{\sin(\theta_2)} = \frac{F}{\sin\left[180\ \text{deg} - (\theta_1 + \theta_2)\right]}$$

$$F_{AC} = F\left[\frac{\sin(\theta_2)}{\sin\left[180\ \text{deg} - (\theta_1 + \theta_2)\right]}\right]$$

$F_{AC} = 239\,\text{lb}$

Problem 2-14

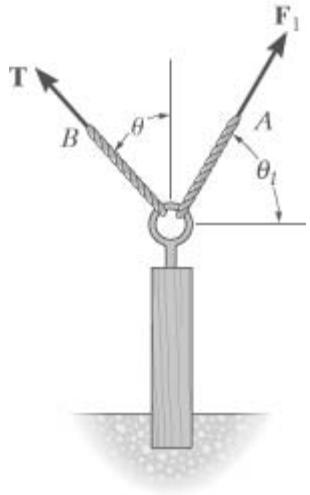
The post is to be pulled out of the ground using two ropes A and B. Rope A is subjected to force F_1 and is directed at angle θ_1 from the horizontal. If the resultant force acting on the post is to be F_R, vertically upward, determine the force $\mathbf{T}$ in rope B and the corresponding angle θ.

Given:

$F_R = 1200\ \text{lb}$

$F_1 = 600\ \text{lb}$

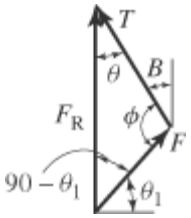
$\theta_1 = 60\ \text{deg}$



Solution:

$$T = \sqrt{F_1^{\,2} + F_R^{\,2} - 2\,F_1\,F_R\cos(90\ \text{deg} - \theta_1)}$$

$T = 744\,\text{lb}$

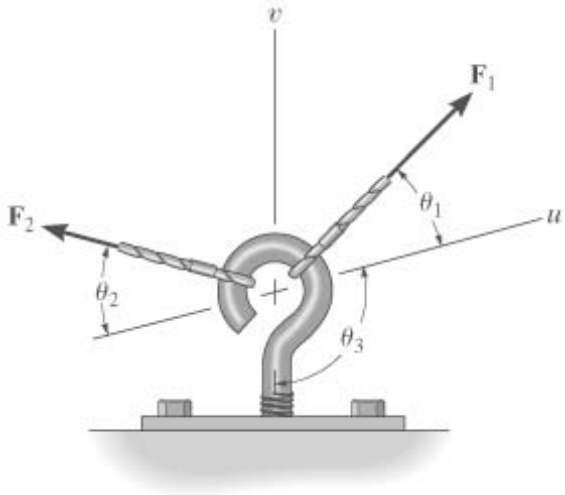


$$\frac{\sin(\theta)}{F_R} = \frac{\sin(90 - \theta_1)}{T}$$

$$\theta = \text{asin}\left(\sin(90\ \text{deg} - \theta_1)\,\frac{F_1}{T}\right) \qquad \theta = 23.8\,\text{deg}$$

Problem 2-15

Resolve the force $\mathbf{F_1}$ into components acting along the *u* and *v* axes and determine the magnitudes of the components.



Given:

$F_1 = 250\ \text{N}$

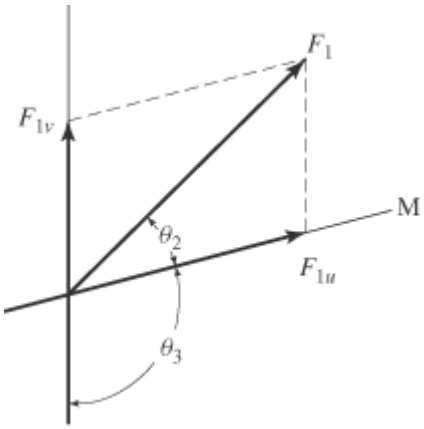
$F_2 = 150\ \text{N}$

$\theta_1 = 30\ \text{deg}$

$\theta_2 = 30\ \text{deg}$

$\theta_3 = 105\ \text{deg}$

Solution:



$$\frac{F_{1v}}{\sin(\theta_1)} = \frac{F_1}{\sin(\theta_3)}$$

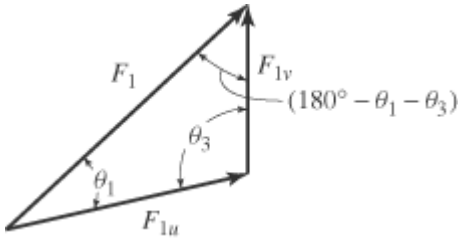
$$F_{1v} = F_1\left(\frac{\sin(\theta_1)}{\sin(\theta_3)}\right)$$

$F_{1v} = 129\,\text{N}$

$$\frac{F_{1u}}{\sin(180\ \text{deg} - \theta_1 - \theta_3)} = \frac{F_1}{\sin(\theta_3)}$$

$$F_{1u} = F_1\left(\frac{\sin(180\ \text{deg} - \theta_1 - \theta_3)}{\sin(\theta_3)}\right)$$

$F_{1u} = 183\ \text{N}$



Problem 2-16

Resolve the force $\mathbf{F_2}$ into components acting along the *u* and *v* axes and determine the magnitudes of the components.

Given:

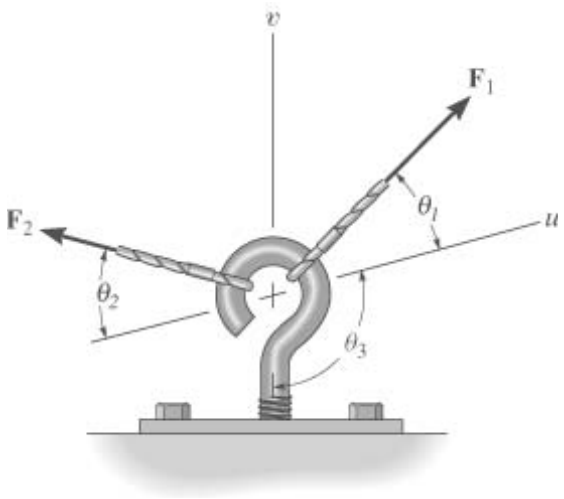
$F_1 = 250\ \text{N}$

$F_2 = 150$ N

$\theta_1 = 30$ deg

$\theta_2 = 30$ deg

$\theta_3 = 105$ deg



Solution:

$$\frac{F_{1v}}{\sin(\theta_1)} = \frac{F_2}{\sin(180\ \text{deg} - \theta_3)}$$

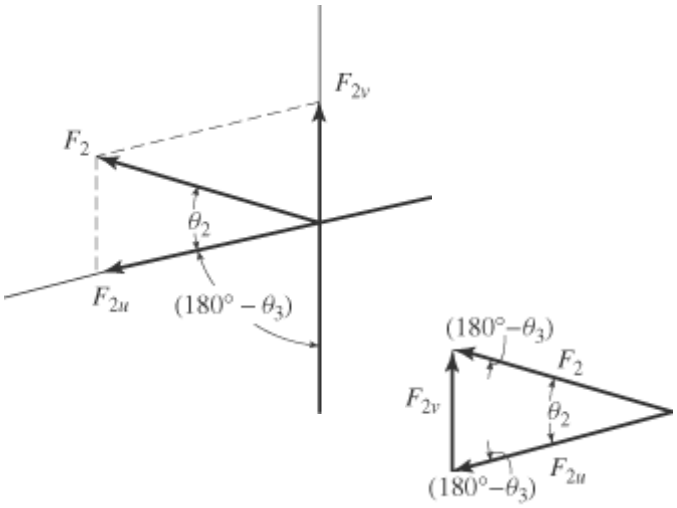
$$F_{1v} = F_2 \left(\frac{\sin(\theta_1)}{\sin(180\ \text{deg} - \theta_3)} \right)$$

$F_{1v} = 77.6\,\text{N}$

$$\frac{F_{2u}}{\sin(180\ \text{deg} - \theta_3)} = \frac{F_2}{\sin(180\ \text{deg} - \theta_3)}$$

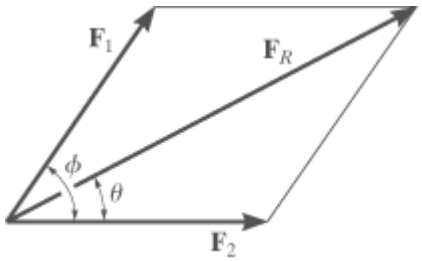
$$F_{2u} = F_2 \left(\frac{\sin(180\ \text{deg} - \theta_3)}{\sin(180\ \text{deg} - \theta_3)} \right)$$

$F_{2u} = 150$ N



Problem 2-17

Determine the magnitude and direction of the resultant force $\mathbf{F_R}$. Express the result in terms of the magnitudes of the components $\mathbf{F_1}$ and $\mathbf{F_2}$ and the angle ϕ.



Solution:

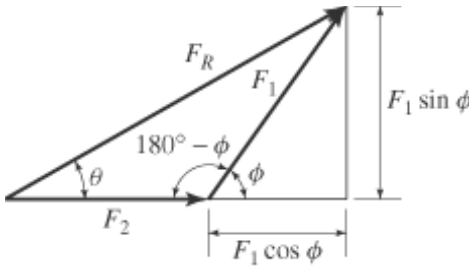
$$F_R^2 = F_1^2 + F_2^2 - 2F_1\,F_2\cos(180\ \text{deg} - \phi)$$

Since $\cos(180\,\text{deg} - \phi) = -\cos(\phi)$,

$$F_R = \sqrt{F_1^2 + F_2^2 + 2\,F_1\,F_2\,\cos(\phi)}$$

From the figure,

$$\tan(\theta) = \frac{F_1\,\sin(\phi)}{F_2 + F_1\,\cos(\phi)}$$



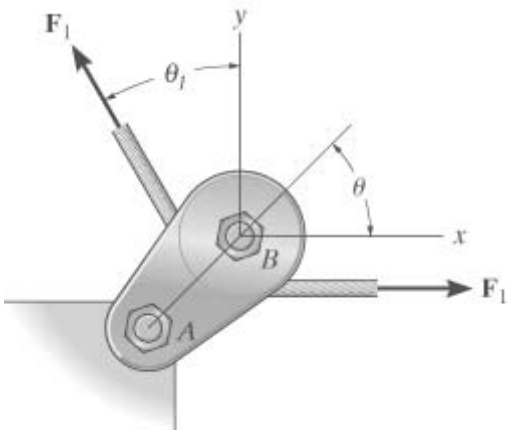
Problem 2-18

If the tension in the cable is $\mathbf{F_1}$, determine the magnitude and direction of the resultant force acting on the pulley. This angle defines the same angle θ of line *AB* on the tailboard block.

Given:

$F_1 = 400$ N

$\theta_1 = 30$ deg



Solution:

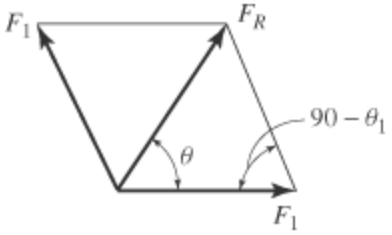
$$F_R = \sqrt{F_1^2 + F_1^2 - 2F_1F_1\cos(90\ \text{deg} - \theta_1)}$$

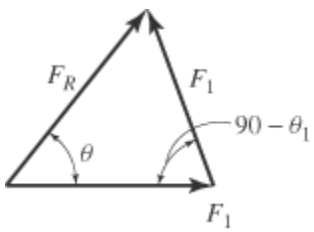
$F_R = 400$ N

$$\frac{\sin(90\ \text{deg} - \theta)}{F_R} = \frac{\sin(\theta_1)}{F_1}$$

$$\theta = 90\ \text{deg} - \text{asin}\left(\frac{F_R}{F_1}\sin(\theta_1)\right)$$

$\theta = 60\,\text{deg}$





Problem 2-19

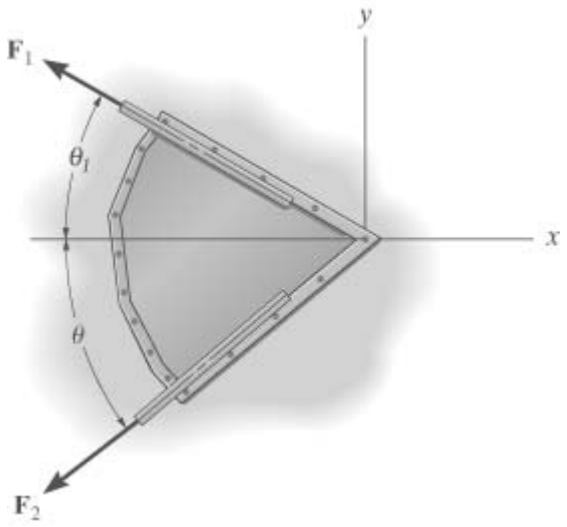
The riveted bracket supports two forces. Determine the angle θ so that the resultant force is directed along the negative *x* axis. What is the magnitude of this resultant force?

Given:

$F_1 = 60$ lb

$F_2 = 70$ lb

$\theta_1 = 30$ deg

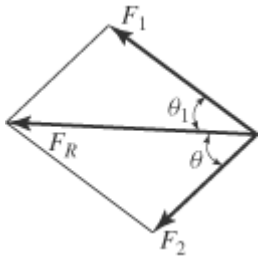


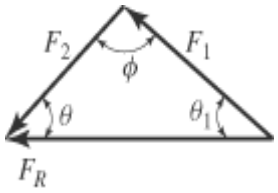
Solution:

$$\frac{\sin(\theta)}{F_1} = \frac{\sin(\theta_1)}{F_2}$$

$$\theta = \operatorname{asin}\left(\sin(\theta_1)\,\frac{F_1}{F_2}\right)$$

$\theta = 25.4\,\text{deg}$





$\phi = 180\ \text{deg} - \theta - \theta_1$

$\phi = 124.6\,\text{deg}$

$$R = \sqrt{F_1^{\,2} + F_2^{\,2} - 2F_1F_2\cos(\phi)}$$

$R = 115\,\text{lb}$

Problem 2-20

The plate is subjected to the forces acting on members *A* and *B* as shown. Determine the magnitude of the resultant of these forces and its direction measured clockwise from the positive *x* axis.

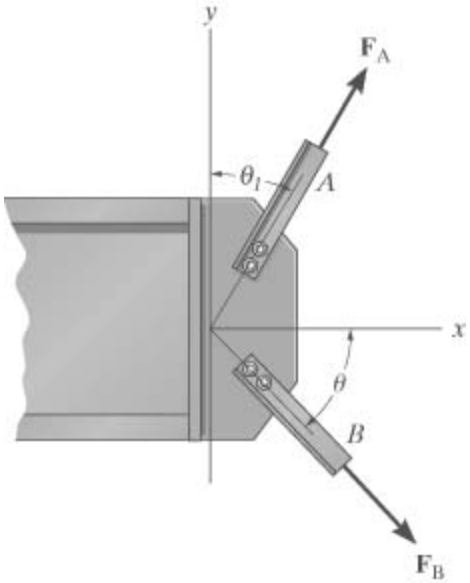
Given:

$F_A = 400$ lb

$F_B = 500$ lb

$\theta_1 = 30 \text{ deg}$

$\theta = 60 \text{ deg}$



Solution:

Cosine law:

$$F_R = \sqrt{F_B{}^2 + F_A{}^2 - 2F_B F_A \cos\left(90 \text{ deg} - \theta + \theta_1\right)}$$

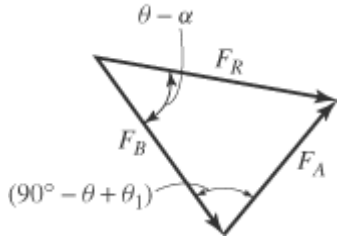
$F_R = 458 \text{ lb}$

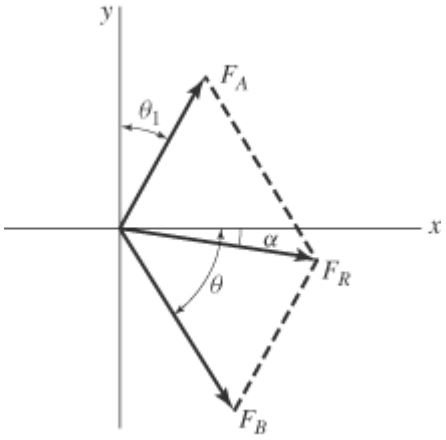
Sine law:

$$\frac{\sin\left(90 \text{ deg} - \theta + \theta_1\right)}{F_R} = \frac{\sin\left(\theta - \alpha\right)}{F_A}$$

$$\alpha = \theta - \text{asin}\left(\sin\left(90 \text{ deg} - \theta + \theta_1\right)\frac{F_A}{F_R}\right)$$

$\alpha = 10.9 \text{ deg}$





Problem 2-21

Determine the angle θ for connecting member B to the plate so that the resultant of $\mathbf{F_A}$ and $\mathbf{F_B}$ is directed along the positive x axis. What is the magnitude of the resultant force?

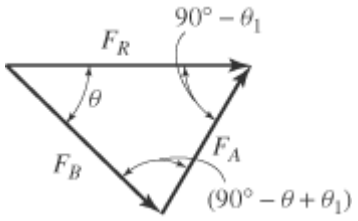
Given:

$F_A = 400 \text{ lb}$

$F_B = 500 \text{ lb}$

$\theta_1 = 30 \text{ deg}$

Solution:



Sine law:

$$\frac{\sin(\theta)}{F_A} = \frac{\sin(90\ \text{deg} - \theta_1)}{F_B}$$

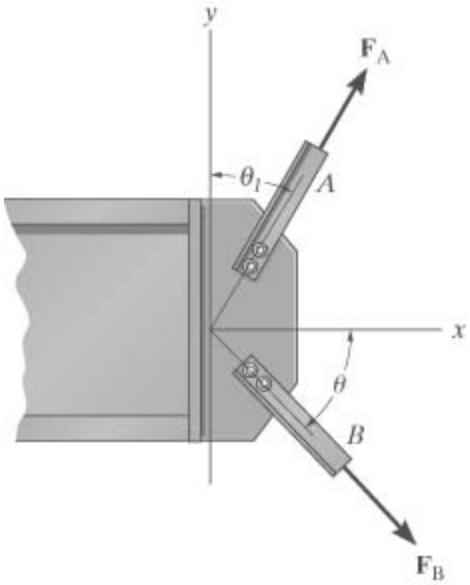
$$\theta = \text{asin}\left(\sin(90\ \text{deg} - \theta_1)\ \frac{F_A}{F_B}\right)$$

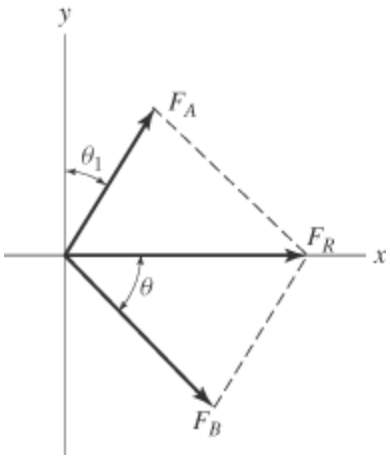
$\theta = 43.9\,\text{deg}$

$$\frac{F_R}{\sin(90\ \text{deg} + \theta_1 - \theta)} = \frac{F_A}{\sin(\theta)}$$

$$F_R = F_A\ \frac{\sin(90\ \text{deg} - \theta + \theta_1)}{\sin(\theta)}$$

$F_R = 561\,\text{lb}$





Problem 2-22

Determine the magnitude and direction of the resultant $\mathbf{F_R} = \mathbf{F_1} + \mathbf{F_2} + \mathbf{F_3}$ of the three forces by first finding the resultant $\mathbf{F'} = \mathbf{F_1} + \mathbf{F_2}$ and then forming $\mathbf{F_R} = \mathbf{F'} + \mathbf{F_3}$.

Given:

$F_1 = 30$ N

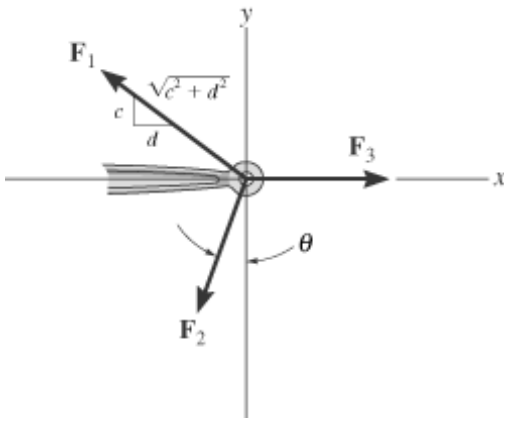
$F_2 = 20$ N

$F_3 = 50$ N

$\theta = 20$ deg

$c = 3$

$d = 4$



Solution:

$$\alpha = \operatorname{atan}\left(\frac{c}{d}\right)$$

$$F' = \sqrt{F_1{}^2 + F_2{}^2 - 2F_1 F_2 \cos(90\ \text{deg} + \theta - \alpha)}$$

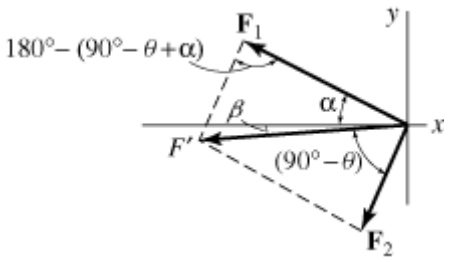
$$F' = 30.9\ \text{N}$$

$$\frac{F'}{\sin((90\ \text{deg} - \theta + \alpha))} = \frac{F_1}{\sin(90\ \text{deg} - \theta - \beta)}$$

$$\beta = 90\ \text{deg} - \theta - \operatorname{asin}\left(F_1\ \frac{\sin(90\ \text{deg} - \theta + \alpha)}{F'}\right)$$

$$\beta = 1.5\ \text{deg}$$

Now add in force F_3.



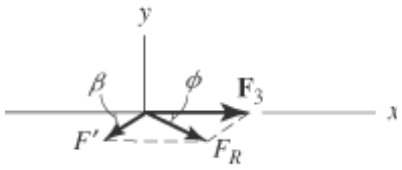
$$F_R = \sqrt{F'^2 + F_3{}^2 - 2F'\ F_3 \cos(\beta)}$$

$$F_R = 19.2\ \text{N}$$

$$\frac{F_R}{\sin(\beta)} = \frac{F'}{\sin(\phi)}$$

$$\phi = \operatorname{asin}\left(F'\ \frac{\sin(\beta)}{F_R}\right)$$

$$\phi = 2.4\ \text{deg}$$



Problem 2-23

Determine the magnitude and direction of the resultant $\mathbf{F_R} = \mathbf{F_1} + \mathbf{F_2} + \mathbf{F_3}$ of the three forces by first finding the resultant $\mathbf{F'} = \mathbf{F_2} + \mathbf{F_3}$ and then forming $\mathbf{F_R} = \mathbf{F'} + \mathbf{F_1}$.

Given:

$$F_1 = 30\ \text{N}$$

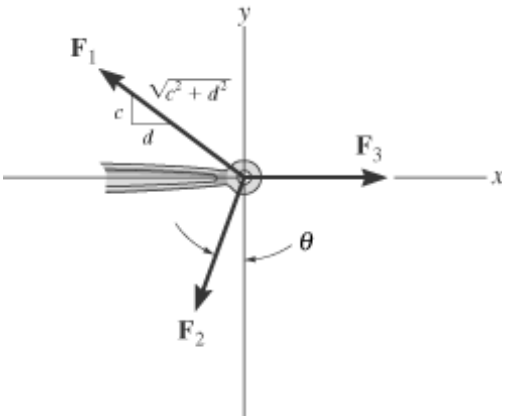
$$F_2 = 20\ \text{N}$$

$F_3 = 50\ \text{N}$

$\theta = 20\ \text{deg}$

$c = 3$

$d = 4$

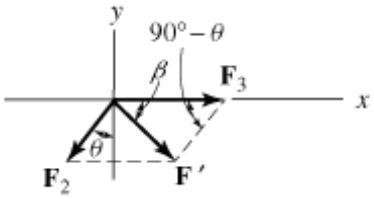


Solution:

$$F' = \sqrt{F_2^2 + F_3^2 - 2F_2F_3\cos((90\ \text{deg} - \theta))}$$

$F' = 47.07\ \text{N}$

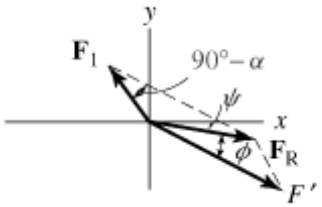
$$\frac{F_2}{\sin(\beta)} = \frac{F'}{\sin(90\ \text{deg} - \theta)}$$



$$\beta = \text{asin}\left(F_2\ \frac{\sin(90\ \text{deg} - \theta)}{F'}\right)$$

$\beta = 23.53\,\text{deg}$

$$\alpha = \text{atan}\left(\frac{c}{d}\right)$$



$\gamma = \alpha - \beta$

$$F_R = \sqrt{F'^2 + F_1^2 - 2F'F_1\cos(\gamma)}$$

$F_R = 19.2\ \text{N}$

$$\frac{F_R}{\sin(\gamma)} = \frac{F_1}{\sin(\phi)}$$

$$\phi = \text{asin}\left(F_1\ \frac{\sin(\gamma)}{F_R}\right)$$

$\phi = 21.16\,\text{deg}$

$\psi = \beta - \phi$

$\psi = 2.37\,\text{deg}$