

SI EDITION

THIRD EDITION

ENGINEERING MECHANICS

# STATICS

SOLUTION MANUAL

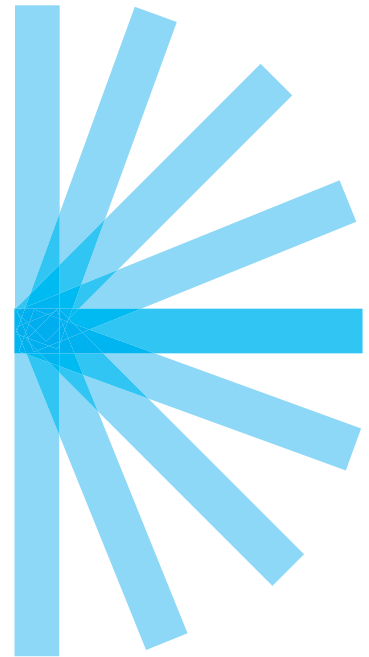
ANDREW PYTEL    JAAN KIOUSALAAS

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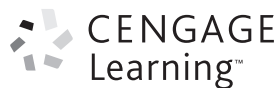
*Engineering Mechanics*

*Statics*

Third Edition, SI



# SOLUTION MANUAL



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# Chapter 1

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## 1.1

$$(a) \ m = \frac{150 \text{ N}}{1.64} = 91.46 \text{ kg} \quad \blacklozenge$$

$$(b) \ W = mg = (91.46)(9.81) = 897.2 \text{ N} \quad \blacklozenge$$

## 1.2

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

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

## 1.3

$$(a) \ 40000 \text{ N} \cdot \text{cm} = 40000 \text{ N} \cdot \text{cm} \times \frac{1 \text{ kN}}{1000 \text{ N}} \times \frac{1 \text{ m}}{100 \text{ cm}} = 0.4 \text{ kN} \cdot \text{m} \quad \blacklozenge$$

$$(b) \ 1 \text{ bar} = 10^5 \text{ Pa} = 10^5 \text{ N/m}^2 \times \frac{1 \text{ kN/m}^2}{1000 \text{ N/m}^2} = 100 \text{ kN/m}^2 = 100 \text{ kPa} \quad \blacklozenge$$

$$(c) \ 6 \text{ m/s} = 6 \text{ m/s} \times \frac{1000 \text{ mm}}{1 \text{ m}} \times \frac{3600 \text{ s}}{1 \text{ h}} = 2.16 \times 10^7 \text{ mm/h} \quad \blacklozenge$$

$$(d) \ 500 \text{ g/mm} = 500 \text{ g/mm} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{1000 \text{ mm}}{1 \text{ m}} = 500 \text{ g/m} \quad \blacktriangleleft$$

## 1.4

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

Rounding off to four significant digits

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

## 1.5

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

### 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:  $[k] = \left[\frac{F}{x}\right] = \left[\frac{ML}{T^2}\right]\left[\frac{1}{L}\right] = \left[\frac{M}{T^2}\right] \quad \blacklozenge$

### 1.8

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

### 1.9

$$y = kx^2 \quad (\text{where } k = 1.0)$$

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 explicitly) are understood to be  $\text{m}^{-1}$

### 1.10

$$[I] = [mR^2] = [ML^2] \quad \blacklozenge$$



### 1.11

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

$$\begin{aligned}[L] &= [A][T^2] - [B][LT^{-1}][T] \\ \therefore [A] &= [LT^{-2}] \blacktriangleleft \quad [B] = [1] \text{ (dimensionless)} \blacktriangleleft\end{aligned}$$

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

$$\begin{aligned}[L] &= [A][LT^{-1}][T]e^{[B][T]} \\ [B][T] &= [1] \quad \therefore [B] = [T^{-1}] \blacktriangleleft \\ [L] &= [A][LT^{-1}][T] \quad \therefore [A] = [1] \blacktriangleleft\end{aligned}$$

### 1.12

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

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

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

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

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

$$[\omega t] = [\omega][T] = [1] \quad \therefore [\omega] = [T^{-1}] \quad \blacklozenge$$

### 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)

$$\text{Dim } R^2 = [L^2] \quad (2)$$

◆

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

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

### 1.14

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

### 1.15

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

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

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

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

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

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

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

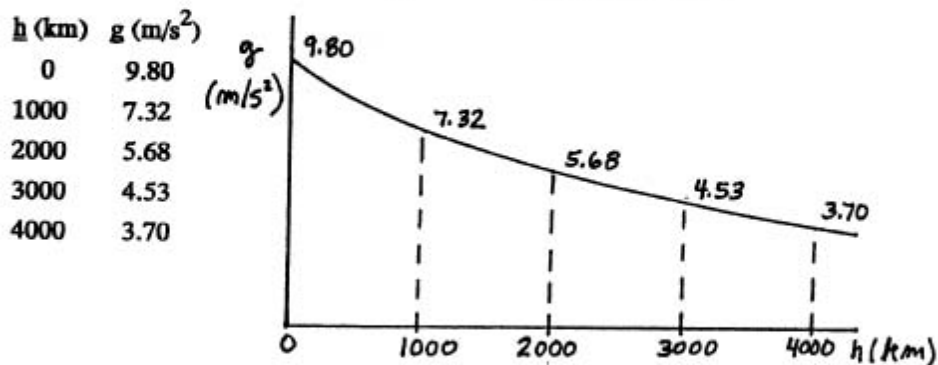
1.18

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

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

1.19

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



1.20

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

$$W = \frac{W_e}{10} = \frac{GM_em}{(R_e + h)^2} = \frac{GM_em}{10R_e^2} \quad (R_e + h)^2 = 10R_e^2$$

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

1.21

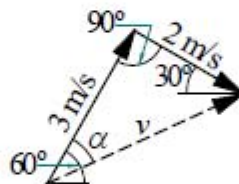
$$R = R_e + R_m + d = 6378 + 1737 + 384 \times 10^3$$

$$= 392.1 \times 10^3 \text{ km} = 392.1 \times 10^6 \text{ m}$$

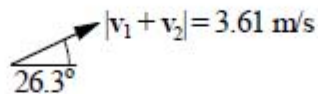
$$F = G \frac{M_e M_m}{R^2} = (6.67 \times 10^{-11}) \frac{(5.974 \times 10^{24})(0.07348 \times 10^{24})}{(392.1 \times 10^6)^2}$$

$$= 1.904 \times 10^{20} \text{ N} \quad \blacktriangleleft$$

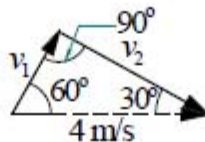
1.22



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



1.23

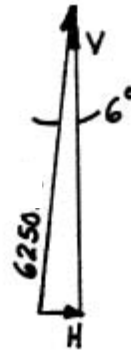


$$v_1 = 4 \sin 30^\circ = 2 \text{ m/s} \quad \blacktriangleleft \quad v_2 = 4 \sin 60^\circ = 3.46 \text{ m/s} \quad \blacktriangleleft$$

1.24

Horizontal:  $H = 6250 \sin 6^\circ = 653 \text{ N } (\rightarrow) \blacklozenge$

Vertical:  $V = 6250 \cos 6^\circ = 6220 \text{ N } (\uparrow) \blacklozenge$



1.25

(a)  $F_x = 200 \cos 30^\circ = 173.2 \text{ N } (\rightarrow) \blacklozenge$

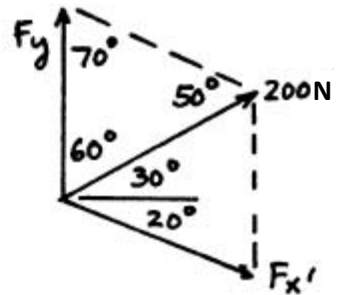
$F_y = 200 \sin 30^\circ = 100.0 \text{ N } (\uparrow) \blacklozenge$

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

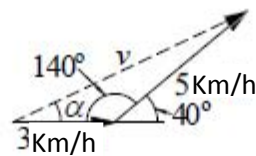
which gives

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

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

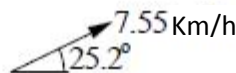


1.26



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

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



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:

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

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

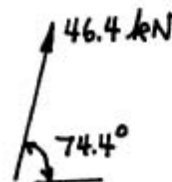
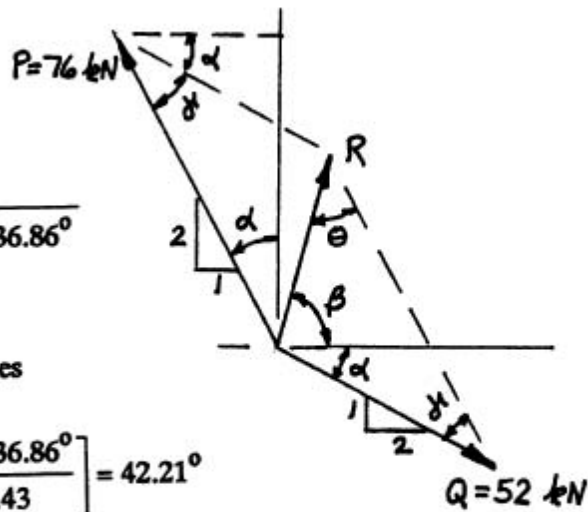
Law of sines:  $\frac{R}{\sin \gamma} = \frac{Q}{\sin \theta}$  which gives

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

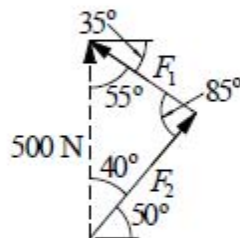
Geometry:  $\beta = 180^\circ - \theta - \gamma - \alpha$

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

Therefore, the resultant of P and Q is:



1.28

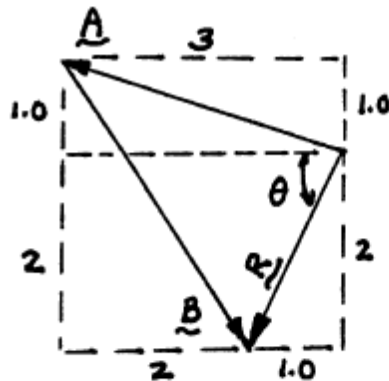


$$\text{Law of sines: } \frac{500}{\sin 85^\circ} = \frac{F_1}{\sin 40^\circ} = \frac{F_2}{\sin 55^\circ}$$

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

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

1.29

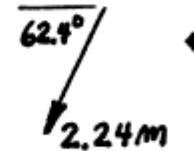


$$\mathbf{R} = \mathbf{A} + \mathbf{B}$$

By inspection of the triangle (dimensions in meters)

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

Therefore, the resultant of A and B is:



1.30

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

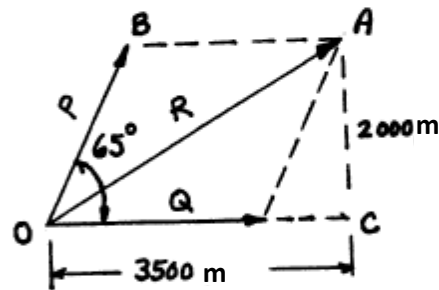
$$P = \frac{2000}{\sin 65^\circ} = 2207 \text{ m}$$

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

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

Therefore, the components are:

2210 ft along OB and 2570 m along OC ♦



1.31

$$\text{Law of sines: } \frac{360}{\sin 95^\circ} = \frac{P_{AB}}{\sin 30^\circ} = \frac{P_{AC}}{\sin 55^\circ}$$

which gives

$$P_{AB} = \frac{360 \sin 30^\circ}{\sin 95^\circ} = 180.7 \text{ N} \quad \blacklozenge$$

$$P_{AC} = \frac{360 \sin 55^\circ}{\sin 95^\circ} = 296 \text{ N} \quad \blacklozenge$$

