Homework 3

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Torque Statics

1 Book

1.1 11.14

(a)

(b)

$$
\begin{aligned}
l_{\mathrm{b}} &= 9.00\,\mathrm{m} \\
w_{\mathrm{b}} &= 300\,\mathrm{N} \\
x_{\mathrm{B,A}} &= 5.00\,\mathrm{m} \\
w_{\mathrm{p}} &= 600\,\mathrm{N}
\end{aligned}
$$

$$
\begin{aligned}
\sum \tau_{\star} &= 0 \\
(F_A)(5\,\mathrm{m}) &= (w_{\mathrm{p}})(5\,\mathrm{m} - x) + (w_{\mathrm{b}})(2.5\,\mathrm{m}) \\
F_A &= \left(0.2\,\mathrm{m}^{-1}\right)\left((600\,\mathrm{N})(5\,\mathrm{m} - x) + (300\,\mathrm{N})(2.5\,\mathrm{m})\right) \\
(0) &= 600\,\mathrm{N} - (120\,\mathrm{N\,m^{-1}})x + 150\,\mathrm{N} \\
(120\,\mathrm{N\,m^{-1}})x &= 750\,\mathrm{N} \\
x &= 6.25\,\mathrm{m}
\end{aligned}
$$

$$x = 6.25\,\mathrm{m} - x_{\mathrm{B,A}} = 1.25\,\mathrm{m}$$

$$\boxed{1.25\,\mathrm{m}}$$

(c)

$$
\begin{aligned}
x_\mathrm{p} &= 7.00\,\mathrm{m} \\
w_\mathrm{p} &= 600\,\mathrm{N} \\
x_\mathrm{b} &= 2.5\,\mathrm{m} \\
w_\mathrm{b} &= 300\,\mathrm{N} \\
x_\mathrm{B} &= ? \\
F_\mathrm{B} &= 900\,\mathrm{N} \\
x_\mathrm{A} &= 0 \\
F_\mathrm{A} &= 0
\end{aligned}
$$

$$
\begin{aligned}
\sum \tau_\star &= 0 \\
(w_\mathrm{b})(x_\mathrm{b}) + (w_\mathrm{p})(x_\mathrm{p}) &= (F_\mathrm{b})(x_\mathrm{b}) \\
x_\mathrm{b} &= \frac{(300\,\mathrm{N})(2.5\,\mathrm{m}) + (600\,\mathrm{N})(7.00\,\mathrm{m})}{900\,\mathrm{N})} \\
x_\mathrm{b} &= 1.5\,\mathrm{m}
\end{aligned}
$$

$$\boxed{x_\mathrm{b} = 1.5\,\mathrm{m}}$$

1.2 11.16

$$
\begin{aligned}
l_\mathrm{(b)eam} &= 4.00\,\mathrm{m} \\
l_\mathrm{(c)able} &= 5.00\,\mathrm{m} \\
l_\mathrm{(w)all} &= 3.00\,\mathrm{m} \\
w_\mathrm{b} &= 190\,\mathrm{N} \\
w_\mathrm{(o)bject} &= 300\,\mathrm{N} \\
\theta_\mathrm{c,b} &= 36.87^\circ
\end{aligned}
$$

(a)

$$
\begin{aligned}
T &= ? \\
T_y &= T\sin(\theta_\mathrm{c,b}) \\
\sum \tau_\star &= 0 \\
\left(\frac{l_\mathrm{b}}{2}\right)(w_\mathrm{b}) + (l_\mathrm{b})(w_\mathrm{o}) &= (l_\mathrm{b})(T_y) \\
T &= \frac{\left(\frac{4.00\,\mathrm{m}}{2}\right)(190\,\mathrm{N}) + (4.00\,\mathrm{m})(300\,\mathrm{N})}{(4.00\,\mathrm{m})(\sin(36.87^\circ))} \\
T &= 658.3\,\mathrm{N}
\end{aligned}
$$

$$\boxed{T = 658.3\,\mathrm{N}}$$

(b)

$$\begin{aligned} F_x &= ? \\ \sum F_x &= 0 \\ F_x &= T_x \\ &= T\cos(\theta_{\mathrm{c,b}}) \\ &= (658.3\,\mathrm{N})(\cos(36.87^\circ) \\ F_x &= 526.6\,\mathrm{N} \end{aligned}$$

$$\begin{aligned} F_y &= ? \\ \sum F_y &= 0 \\ F_y + T_y &= w_{\mathrm{b}} + w_{\mathrm{o}} \\ F_y + (658.3\,\mathrm{N})(\sin(36.87^\circ)) &= 190\,\mathrm{N} + 300\,\mathrm{N} \\ F_y &= 190\,\mathrm{N} + 300\,\mathrm{N} - (658.3\,\mathrm{N})(\sin(36.87^\circ) \\ F_y &= 95.02\,\mathrm{N} \end{aligned}$$

$$\boxed{F_x = 526.6\,\mathrm{N}, F_y = 95.02\,\mathrm{N}}$$

1.3 11.23

$$\begin{aligned} F_1 = F_2 &= 6.30\,\mathrm{N} \\ l_{F_1,O} &= 3.00\,\mathrm{m} \end{aligned}$$

(a)

$$\begin{aligned} l &= ? \\ \sum \tau_\star &= 6.50\,\mathrm{N\,m} \\ (F_2)(l_{F_1,0} + l) &= 6.50\,\mathrm{N\,m} + (F_1)(l_{F_1,O}) \\ (6.30\,\mathrm{N})(3.00\,\mathrm{m} + l) &= 6.50\,\mathrm{N\,m} + (6.30\,\mathrm{N})(3.00\,\mathrm{N}) \\ l &= 1.032\,\mathrm{m} \end{aligned}$$

$$\boxed{l = 1.032\,\mathrm{m}}$$

(b)

$$\boxed{\text{clockwise}}$$

(c)

$$
\begin{aligned}
l &= ? \\
F_2 &= 0 \\
\sum \tau_\star &= (6.50\,\mathrm{N\,m})(3.00\,\mathrm{m} + l) \\
-(F_1)(l) &= (6.50\,\mathrm{N\,m}) \\
-(6.30\,\mathrm{N})(l) &= (6.50\,\mathrm{N\,m}) \\
l &= -1.032\,\mathrm{m}
\end{aligned}
$$

$$\boxed{l = -1.032\,\mathrm{m}}$$

1.4 11.45

$$
\begin{aligned}
h &= 0.300\,\mathrm{m} \\
x &= 0.080\,\mathrm{m} \\
\theta &= 60^\circ \\
F_1 &= ? \\
F_2 &= ?
\end{aligned}
$$

$$
\begin{aligned}
\sum \tau_\star &= 0 \\
(F_2)(h) - (F_{1_y})(x) &= 0 \\
(F_2)(0.300\,\mathrm{m}) &= (F_1 \sin(60^\circ))(0.080\,\mathrm{m}) \\
F_1 &= F_2(4.330)
\end{aligned}
$$

$$\boxed{F_1 = F_2(4.330)}$$

1.5 11.49

$$
\begin{aligned}
\theta &= 25.0^\circ \\
\phi &= 35.0^\circ \\
l_{\mathrm{cog}} &= 1.1\,\mathrm{m} \\
m_{\mathrm{p}} &= 82.0\,\mathrm{kg} \\
l_{\mathrm{(h)ands}} &= 1.40\,\mathrm{m} \\
l_{\mathrm{(p)erson}} &= 1.90\,\mathrm{m}
\end{aligned}
$$

(a)

$$\begin{aligned}
\sum \tau_\star &= 0 \\
(T_y)(l_\mathrm{h}) &= (w_\mathrm{p})(l_\mathrm{cog})(\cos(\phi)) \\
T &= (\frac{m_\mathrm{p})(10\,\mathrm{m\,s^{-2}})(l_\mathrm{cog})(\cos(\phi))}{(l_\mathrm{h})(\cos(\phi-\theta))} \\
T &= \frac{(82.0\,\mathrm{kg})(10\,\mathrm{m\,s^{-2}})(1.1\,\mathrm{m})(\cos(35.0^\circ))}{(1.40\,\mathrm{m})(\cos(10^\circ))} \\
T &= 535.9\,\mathrm{N}
\end{aligned}$$

$$\boxed{T = 535.9\,\mathrm{N}}$$

(b)

$$\begin{aligned}
\sum F_x &= 0 \\
N &= T_x \\
N &= (535.9\,\mathrm{N})(\sin(25.0^\circ) \\
N &= 226.5\,\mathrm{N}
\end{aligned}$$

$$\begin{aligned}
\sum F_y &= 0 \\
Ty + f &= w_p \\
(535.9\,\mathrm{N})(\cos(25.0^\circ)) + f &= (82.0\,\mathrm{kg})(10\,\mathrm{m\,s^{-2}}) \\
f &= 334.3\,\mathrm{N}
\end{aligned}$$

$$\boxed{N = 226.5\,\mathrm{N}, f = 334.3\,\mathrm{N}}$$

(c)

$$\begin{aligned}
f &= \mu N \\
\mu &= \frac{f}{N} \\
&= \frac{334.3\,\mathrm{N}}{226.5\,\mathrm{N}} \\
\mu &= 1.476
\end{aligned}$$

$$\boxed{\mu = 1.476}$$

1.6 11.53

$$
\begin{aligned}
l_{\text{(b)eam}} &= 1.50\,\text{m} \\
m_{\text{b}} &= 19.0\,\text{kg} \\
m_{\text{(s)ign}} &= 35.0\,\text{kg} \\
l_{\text{s}} &= 1.20\,\text{m} \\
x_{w_b,w_a} &= 32.0\,\text{cm} \\
l_{\text{(c)able}} &= 2.20\,\text{m}
\end{aligned}
$$

(a)

$$
\begin{aligned}
\cos(\theta) &= \frac{1.5\,\text{m}}{2.2\,\text{m}} \\
\theta &= 68.2^\circ \\
T_{\text{w}} &= \frac{(m_{\text{s}})(10\,\text{m}\,\text{s}^{-2})}{2} \\
&= \frac{(35.0\,\text{kg})(10\,\text{m}\,\text{s}^{-2})}{2} \\
T_{\text{w}} &= 175\,\text{N} \\
\sum \tau_\star &= 0 \\
(T_y)(l_{\text{b}}) &= (w_{\text{b}})\left(\frac{l_{\text{b}}}{2}\right) + (T_{\text{w}})(l_{\text{b}} + x_{w_b,w_a}) \\
T &= \frac{(190.0\,\text{N})(0.75\,\text{m}) + (175\,\text{N})(1.50\,\text{m} + 0.32\,\text{m})}{(1.50\,\text{m})(\sin(68.2^\circ)} \\
T &= 331.0\,\text{N}
\end{aligned}
$$

$$\boxed{T = 331.0\,\text{N}}$$

(b)

$$
\begin{aligned}
\sum F_y &= 0 \\
F_y + T_y &= w_{\text{b}} + 2T_{\text{w}} \\
F_y &= (190.0\,\text{N}) + 2(175\,\text{N}) - (331.0\,\text{N})(\sin(68.2^\circ)) \\
F_y &= 232.7\,\text{N}
\end{aligned}
$$

$$\boxed{F_y = 232.7\,\text{N}}$$

1.7 11.71

$$
\begin{aligned}
m_{\text{crate}} &= 200\,\text{kg} \\
l_{\text{crate}} &= 1.25\,\text{m} \\
h_{\text{crate}} &= 0.500\,\text{m} \\
\theta &= 45.0^\circ \\
F_1 &= ? \\
F_2 &= ?
\end{aligned}
$$

$$
\begin{aligned}
\cos(\theta) &= \frac{x_{\text{cog}}}{\frac{1}{2}l_{\text{crate}}} \\
x_{\text{cog}} &= (0.625\,\text{m})(\cos(45.0^\circ)) \\
x_{\text{cog}} &= 0.442\,\text{m} \\
\cos(\theta) &= \frac{x_{F_2}}{1.25\,\text{m}} \\
x_{F_2} &= 0.884\,\text{m}
\end{aligned}
$$

$$
\begin{aligned}
\sum \tau_\star &= 0 \\
(F_2)(x_{F_2}) &= (w_{\text{crate}})(x_{\text{cog}}) \\
F_2 &= \frac{(2000\,\text{N})(0.442\,\text{m})}{0.884\,\text{m}} \\
F_2 &= 1000\,\text{N} \\
\sum F_y &= 0 \\
F_1 + F_2 &= w_{\text{crate}} \\
F_1 &= 2000\,\text{N} - 1000\,\text{N} \\
F_1 &= 1000\,\text{N}
\end{aligned}
$$

$$\boxed{F_1 = 1000\,\text{N}, F_2 = 1000\,\text{N}}$$

They share an equal upward force on the crate.

1.8 11.75

$$
\begin{aligned}
l_{\text{gate}} &= 4.00\,\text{m} \\
h_{\text{gate}} &= 2.00\,\text{m} \\
w_{\text{gate}} &= 550\,\text{N} \\
\theta &= 30.0^\circ \\
T &= ? \\
T_x &= T\cos(30^\circ) \\
T_y &= T\sin(30^\circ) \\
l_{\text{cog}} &= 2.00\,\text{m}
\end{aligned}
$$

(a)

$$
\begin{aligned}
\sum \tau_\star &= 0 \\
(T_y)(l_{\text{gate}}) + (T_x)(h_{\text{gate}}) &= (w_{\text{gate}})\left(\frac{1}{2}l_{\text{gate}}\right) \\
T &= \frac{(550\,\text{N})(2.00\,\text{m})}{\sin(30^\circ)(4.00\,\text{m}) + (\cos(30^\circ))(2.00\,\text{m})} \\
T &= 294.7\,\text{N}
\end{aligned}
$$

$$\boxed{T = 294.7\,\text{N}}$$

(b)

$$
\begin{aligned}
\sum F_x &= 0 \\
F_x &= T_x \\
F_x &= (294.7\,\text{N})(\cos(30^\circ)) \\
F_x &= 255.2\,\text{N}
\end{aligned}
$$

$$\boxed{F_x = 255.2\,\text{N}}$$

(c)

$$
\begin{aligned}
\sum F_y &= 0 \\
F_{y_B} + F_{y_A} + T_y &= w_{\text{gate}} \\
F_{y_B} + F_{y_A} &= 550\,\text{N} - (294.7\,\text{N})(\sin(30^\circ)) \\
F_{y_B} + F_{y_A} &= 401.5\,\text{N}
\end{aligned}
$$

$$\boxed{F_{y_B} + F_{y_A} = 401.5\,\text{N}}$$

1.9 11.81

$$\begin{aligned}
\mu &= 0.49 \\
l_{\mathrm{B,A}} &= 2.00\,\mathrm{m} \\
l_{\mathrm{(d)oor,(wh)eel}} &= 0.50\,\mathrm{m} \\
w_{\mathrm{d}} &= 958\,\mathrm{N} \\
\vec{F} &= ? \\
h &= ?
\end{aligned}$$

(a)

$$h = 1.43\,\mathrm{m}$$

$$\begin{aligned}
\sum F_y &= 0 \\
N_A + N_B &= w_{\mathrm{d}} \\
N_A + N_B &= 958\,\mathrm{N}
\end{aligned}$$

$$\begin{aligned}
\sum F_x &= 0 \\
f_A + f_B &= F \\
\mu N_A + \mu N_B &= F \\
\mu(N_A + N_B) &= F \\
(0.49)(958\,\mathrm{N}) &= F \\
F &= 469.4\,\mathrm{N}
\end{aligned}$$

$$\begin{aligned}
\sum \tau_\star &= 0 \\
(w_{\mathrm{d}})\left(\frac{l_{\mathrm{B,A}}}{2}\right) &= (l_{\mathrm{A,B}})(N_A) + (F)(h) \\
N_A &= \frac{(w_d)\left(\frac{l_{\mathrm{B,A}}}{2}\right) - (F)(h)}{l_{\mathrm{A,B}}} \\
N_A &= \frac{(958\,\mathrm{N})(1.00\,\mathrm{m}) - (469.4\,\mathrm{N})(1.43\,\mathrm{m})}{2.00\,\mathrm{m}} \\
N_A &= 143.4\,\mathrm{N}
\end{aligned}$$

$$\begin{aligned}
N_A + N_B &= w_{\mathrm{d}} \\
N_B &= 958\,\mathrm{N} - 143.4\,\mathrm{N} \\
N_B &= 814.6\,\mathrm{N}
\end{aligned}$$

$$\boxed{N_A = 143.4\,\mathrm{N}, N_B = 814.6\,\mathrm{N}}$$

(b) $N_A = 0$

$$\begin{aligned}
\sum \tau_\star &= 0 \\
(w_\mathrm{d})\left(\frac{l_\mathrm{B,A}}{2}\right) &= (l_\mathrm{A,B})(N_A) + (F)(h) \\
h &= \frac{(w_\mathrm{d})\left(\frac{l_\mathrm{B,A}}{2}\right) - (l_\mathrm{A,B})(N_A)}{F} \\
h &= \frac{(958\,\mathrm{N})(1.00\,\mathrm{m}) - (0)}{469.4\,\mathrm{N}} \\
h &= 2.041\,\mathrm{m}
\end{aligned}$$

$$\boxed{h = 2.041\,\mathrm{m}}$$

2 Lab Manual

2.1 370

On Paper PDF

2.2 372

$$\begin{aligned}
\cos(\theta) &= \frac{N_{1_y}}{N_1} \\
N_{1_y} &= (N_1)(\cos(\theta)) \\
\sin(\theta) &= \frac{w_y}{w} \\
w_y &= (w)(\sin(\theta)) \\
\sum \tau_\star &= 0 \\
(N_1)(\cos(\theta)) + N_2 &= (w)(\sin(\theta)) \\
mg &= (mg)(\cos(\theta)) + mg \\
\theta &= \arccos(0)
\end{aligned}$$

Not sure how to solve