Problem 1.

$$F = ma = f$$
$$fR = I\varepsilon$$
$$I = \frac{2}{5}mR^2$$
$$\frac{\omega_0}{R\varepsilon} > \frac{v_0}{a}$$
$$\frac{\omega_0 I}{fR^2} > \frac{v_0 m}{f}$$
$$\omega_0 > \frac{5v_0}{2\omega_0}$$

Problem 2.

$$F(x-d) = I\frac{d\omega}{dt}$$

Do integral on both sides,

$$\int_{t_1}^{t_2} Fdt(x-d) = I\omega$$

and

$$J = \int_{t_1}^{t_2} Fdt = mv$$
$$mv(x-d) = I\omega$$
$$x = \frac{I\omega}{mv} + d = \frac{I}{md} + d \approx 0.71m$$

Problem 3.

$$\omega = \frac{19200}{60} \cdot 2\pi = 640\pi \,\mathrm{rad/s}$$
$$\Omega = \frac{\theta}{t} = \frac{1.1 \times 10^{-6}}{5 \times 3600} \cdot \frac{\pi}{180} \approx 1.07 \times 10^{-2} \,\mathrm{rad/s}$$
$$\tau = L\Omega = I\omega\Omega = \frac{1}{4}md^2\omega\Omega = 2.44 \times 10^{-12} \,\mathrm{kg \cdot m^2/s^2}$$

Problem 4.

(a)

$$G_C L_C \cos 55^\circ + G_B L_B \cos 55^\circ = T L_T \sin 25^\circ$$
$$T = \frac{G_C L_C \cos 55^\circ + G_B L_B \cos 55^\circ}{L_T \sin 25^\circ} \approx 29336N$$

(b)

$$F_x = T \sin 60^\circ = 25406N \quad \text{Pointing to the right}$$
$$F_y = G_C + G_B + T\cos 60^\circ = 40668N \quad \text{Pointing to the sky}$$

Problem 5.

(a)

$$N_B = 2mg \quad \text{Pointing to the sky}$$

$$N_C = mg\tan\theta = \frac{\sqrt{3}}{3}mg \quad \text{Pointing to the left}$$

$$N_A = N_C = \frac{\sqrt{3}}{3}mg \quad \text{Pointing to the right}$$

(b)

$$N = \frac{mg}{\cos\theta} = \frac{2\sqrt{3}}{3}mg$$

Problem 6.

$$F = f + T\sin\theta$$

$$N = G + T\cos\theta = G + (F - f)\cot\theta$$

$$f = \mu_s N = \mu_s[G + (F - f)\cot\theta]$$

$$f = \frac{\mu_s(G + F\cot\theta)}{1 + \mu_s\cot\theta}$$

$$FHx = fH$$

where $x = \frac{h}{X}$

$$Fx = \frac{\mu_s(G + F\cot\theta)}{1 + \mu_s\cot\theta}$$

$$F = \frac{\mu_s G}{(1 + \mu_s\cot\theta)x - \mu_s\cot\theta}$$

(a) When $x = 0.5$,

$$F \approx 399.71N$$

(b) When $x = 0.4$,

$$F \approx 748.77N$$

(c) When $(1 + \mu_s\cot\theta)x - \mu_s\cot\theta < 0$,
F is negative so that the post can not slip.

$$x < \frac{\mu_s\cot\theta}{1 + \mu_s\cot\theta} \approx 0.285$$

So when the force is exerted less than 0.285h to the top, it won't slip.

Problem 7.

(a)

$$P = \frac{RT}{V}$$
$$\frac{dP}{dV} = -\frac{RT}{V^2}$$
$$B = -\frac{dP}{dV/V} = \frac{RT}{V} = P$$

(b)

$$\frac{RT}{V} = \frac{C}{V^\gamma}$$
$$T = \frac{C}{V^{\gamma-1}R}$$
$$P = \frac{C}{V^\gamma}$$
$$\frac{dP}{dV} = -\frac{\gamma C}{V^{\gamma+1}}$$
$$B = -\frac{dP}{dV/V} = \frac{\gamma C}{V^\gamma} = \gamma P$$

Problem 8.

$$P_C = P_0 - \rho g h_2$$
$$2Sv_D = Sv_C$$
$$P_0 + \rho g h_1 = P_C + \frac{1}{2}\rho v_C^2 = P_0 + \frac{1}{2}\rho v_D^2$$
$$\rho g h_1 = \frac{1}{2}\rho v_D^2 = \frac{1}{8}\rho v_C^2$$
$$\rho g h_1 = \frac{1}{2}\rho v_C^2 - \rho g h_2$$
$$h_2 = 3h_1$$

Problem 9.

(a)

$$P_0 + \frac{1}{2}\rho v^2 = P_0 + \rho g y$$
$$v = \sqrt{2gy}$$
$$s = h - y = \frac{1}{2}gt^2$$
$$t = \sqrt{\frac{2(h-y)}{g}}$$
$$D = vt = \sqrt{4(h-y)y}$$

(b)

$$D = vt = 2\sqrt{-\left(y - \frac{h}{2}\right)^2 + \frac{h^2}{4}}$$

When $y = \frac{h}{2}$, D gets its maximum value h

Problem 10.

(a)

$$P = P_0 + \rho g h \approx 1.025 \times 10^5\,\mathrm{Pa}$$

(b)

$$V = \frac{1}{12}\pi\left(\frac{h}{H}D\right)^2 h$$

$$h = \sqrt[3]{\frac{12VH^2}{\pi D^2}}$$

$$P_0 + \frac{1}{2}\rho v^2 = P_0 + \rho g h$$

$$v = \sqrt{2gh} = \sqrt{2g}\sqrt[6]{\frac{12H^2}{\pi D^2}}V^{\frac{1}{6}}$$

$$dV = Svdt = \frac{1}{4}\pi d^2\sqrt{2g}\sqrt[6]{\frac{12H^2}{\pi D^2}}V^{\frac{1}{6}}dt$$

$$V^{-\frac{1}{6}}dV = \frac{1}{4}\pi d^2\sqrt{2g}\sqrt[6]{\frac{12H^2}{\pi D^2}}dt$$

Do integral on both sides,

$$\int_{V_1}^{V_2} V^{-\frac{1}{6}}dV = \int_0^t \frac{1}{4}\pi d^2\sqrt{2g}\sqrt[6]{\frac{12H^2}{\pi D^2}}dt$$

$$t = \frac{\frac{6}{5}V^{\frac{5}{6}}|_{V_1}^{V_2}}{\frac{1}{4}\pi d^2\sqrt{2g}\sqrt[6]{\frac{12H^2}{\pi D^2}}} = 102.86\,\mathrm{s}$$