4-A1

$$\tau = \frac{T}{\frac{\pi d^3}{16}} = \frac{3 \times 10^6 \ \ (Nmm)}{\frac{\pi \times 60^3}{16} \ \ (mm^3)} = 70.7\, MPa$$

4-A2

(1)ねじりモーメント

$$\mathrm{T} = \frac{60}{2\pi} \cdot \frac{L}{n} = \ \frac{60}{2\pi} \cdot \frac{7.5 \times 10^3}{120} = 597\, Nm$$

(2)ねじり応力

$$\tau = \frac{T}{\frac{\pi d^3}{16}} = \frac{597 \times 10^3}{\frac{\pi \times 35^3}{16}} = 70.9\, MPa$$

4-A3

(1)ねじりモーメント

$$\mathrm{T} = \frac{60}{2\pi} \cdot \frac{L}{n} = \ \frac{60}{2\pi} \cdot \frac{3.7 \times 10^3}{40} = 883\, Nm$$

(2)ねじり応力

$$\tau = \frac{T}{\frac{\pi d^3}{16}} = \frac{883 \times 10^3}{\frac{\pi \times 50^3}{16}} = 36.0\, MPa$$

(3)ねじれ角

$$\varphi = \frac{T\ell}{\mathrm{G}I_p} = \frac{883 \times 10^3 \times 300}{80 \times 10^3 \times \frac{\pi \times 50^4}{32}} = 0.00540\, rad\ (0.309°)$$

4-A4

(1)ねじり応力

$$\tau_{AC}=\frac{T_1-T_2+T_3}{\frac{\pi d_1^3}{16}}=\frac{(5-2+3)\times 10^6}{\frac{\pi\times 75^3}{16}}=72.4\,MPa$$

$$\tau_{CD}=\frac{-T_2+T_3}{\frac{\pi d_2^3}{16}}=\frac{(-2+3)\times 10^6}{\frac{\pi\times 50^3}{16}}=40.7\,MPa$$

$$\tau_{DB}=\frac{T_3}{\frac{\pi d_3^3}{16}}=\frac{3\times 10^6}{\frac{\pi\times 45^3}{16}}=168\,MPa$$

(2)ねじれ角

$$\varphi_C=\frac{(T_1-T_2+T_3)\mathrm{a}}{\mathrm{G}I_{p1}}=\frac{(5-2+3)\times 10^6\times 400}{80\times 10^3\times\frac{\pi\times 75^4}{32}}$$

$$=0.00966\,rad\ (0.553°)$$

$$\varphi_D=\varphi_C+\frac{(-T_2+T_3)\mathrm{b}}{\mathrm{G}I_{p2}}=0.00966+\frac{(-2+3)\times 10^6\times 600}{80\times 10^3\times\frac{\pi\times 50^4}{32}}$$

$$=0.0219\,rad\ (1.25°)$$

$$\varphi_B=\varphi_D+\frac{T_3\mathrm{c}}{\mathrm{G}I_{p3}}=0.0219+\frac{3\times 10^6\times 200}{80\times 10^3\times\frac{\pi\times 45^4}{32}}$$

$$=0.0405\,rad\ (2.32°)$$

4-B1

(1)ねじり応力

$$\tau_{\mathrm{AC}} = \frac{2T + 3T}{Z_p} = \frac{5T}{Z_p}$$

$$\tau_{\mathrm{CB}} = \frac{3T}{Z_p}$$

(2)ねじれ角

$$\varphi_C = \frac{(2T + 3T)\,{}^{\ell}/_{3}}{\mathrm{G}I_p} = \frac{5}{3}\frac{T\ell}{GI_p}$$

$$\varphi_B = \varphi_C + \frac{3T\,\frac{2}{3}\,\ell}{GI_p} = \frac{11}{3}\frac{T\ell}{GI_p}\ \left(= \frac{2T\,{}^{\ell}/_{3}}{GI_p} + \frac{3T\ell}{GI_p}\right)$$

4-B2

$$\varphi_C = \frac{(2T + T)\,{}^{\ell}/_{2}}{6\mathrm{G}I_p} = \frac{T\ell}{4GI_p}$$

$$\varphi_B = \varphi_C + \frac{T\,{}^{\ell}/_{2}}{GI_p} = \frac{3}{4}\frac{T\ell}{GI_p}$$

4-B3

右端から距離 x の点の直径 d　と I_p

$$d = \frac{x}{\ell}(d_2 - d_1) + d_1$$

$$I_p = \frac{\pi}{32}d^4 = \frac{\pi}{32}\left[\frac{x}{\ell}(d_2 - d_1) + d_1\right]^4$$

x 点の微小幅 dx のねじれ角 dφ

$$d\varphi = \frac{Tdx}{GI_p}$$

従って，全体のねじれ角は全長で積分して求める。

$$\varphi = \int_0^\ell \frac{Tdx}{GI_p} = \frac{32T}{\pi G}\int_0^\ell \frac{1}{\left[\frac{x}{\ell}(d_2 - d_1) + d_1\right]^4}dx$$

$$= \frac{32T\ell(d_1^2 + d_1 d_2 + d_2^2)}{3\pi G d_1^3 d_2^3}$$

4-B4

＜つり合いの式＞

$$T_A + T_B = T$$

＜変形の式＞

$$\varphi_B = \frac{(T - T_B)\,\ell/2}{3GI_p} - \frac{T_B\,\ell/2}{GI_p} = 0$$

よって，　$T_B = \frac{1}{4}T$　，$T_A = \frac{3}{4}T$

$$\varphi_C = \frac{(T - T_B)\,\ell/2}{3GI_p} = \frac{T\ell}{8GI_p}\ \left(= \frac{T_A\,\ell/2}{3GI_p}\right)$$

4-B5

$$\varphi_{\mathrm{B}} = \frac{TS_0}{4A^2 tG}\frac{2}{3}\ell + \frac{T}{G\dfrac{bt^3}{3}}\frac{\ell}{3} = \frac{8T\ell}{3\pi d^3 tG} + \frac{T\ell}{\pi d t^3 G}$$

4-B6

(1)ねじりモーメント

$$\mathrm{T} = \mathrm{P}\cdot\ell = 100 \times 150 = 15000\ Nmm$$

(2)ボルトの径

$$\mathrm{d} = \sqrt[3]{\frac{16T}{\pi\tau_a}} = \sqrt[3]{\frac{16 \times 15000}{\pi \times 50}} = 11.5\ mm$$