Supplied Equations

Axial stress equations:

$$\sigma = F/A \qquad \text{(M5.13)}$$

$$\begin{aligned} \tau_{xx} &= T/A \quad \text{for tension} \\ \tau_{xx} &= -C/A \quad \text{for compression} \end{aligned} \qquad \text{(B1.93)}$$

Axial strain equations:

$$\begin{aligned} \epsilon_{xx} &= \Delta L/L \quad \text{for tension} \\ \epsilon_{xx} &= -\Delta L/L \quad \text{for compression} \end{aligned} \qquad \text{(B1.95)}$$

Linear elasticity equation:

$$\sigma = E\varepsilon \qquad \text{(M5.14)}$$

$$\tau_{xx} = E\epsilon_{xx} \qquad \text{(B1.117)}$$

Ground reaction force equations:

$$\begin{aligned} F_{gz}(t) &= mg + ma_z(t) \\ F_{gy}(t) &= ma_y(t) \end{aligned}$$

Kinetic energy:

$$E_{\mathsf{kin}}(t) = \frac{1}{2}mv_z^2(t) + \frac{1}{2}mv_y^2(t)$$

Gravitational potential energy:

$$E_{\mathsf{grav}}(t) = mgd_z(t)$$

Force versus velocity relationship for contracting muscle:

$$(F + a)(v + b) = (F_0 + a)\,b \qquad \text{(B10.7)}$$

Net joint power:

$$\text{net joint power} = \mathbf{M} \cdot \boldsymbol{\omega} \quad \text{(W)}$$

Principal stresses in two dimensions:

$$\sigma_{\text{max}} = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \qquad \text{(M5.29)}$$

$$\sigma_{\text{min}} = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \qquad \text{(M5.30)}$$

The angle of the principal stresses in two dimensions:

$$\tan 2\theta_p = \frac{2\tau_{xy}}{\sigma_x - \sigma_y} \qquad \text{(M5.28)}$$

The maximum shear stress in two dimensions:

$$\tau_{\text{max}} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \qquad \text{(M5.31)}$$

Mapping of Cartesian stress tensor to principal stresses in three dimensions:

$$\begin{vmatrix} \tau_{xx} & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \tau_{yy} & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \tau_{zz} \end{vmatrix} \rightarrow \begin{vmatrix} \sigma_1 & 0 & 0 \\ 0 & \sigma_2 & 0 \\ 0 & 0 & \sigma_3 \end{vmatrix} \qquad \text{(B1.99)}$$

using the relation

$$\left(\tau_{ji} - \sigma_k \delta_{ji}\right) \hat{e}_i = 0 \quad \text{for } i, j = x, y, z \text{ and } k = 1, 2, 3 \quad \text{(B1.100)}$$

Von Mises stresses in three dimensions:

$$\sigma_v = \sqrt{\frac{(\tau_{xx}-\tau_{yy})^2+(\tau_{yy}-\tau_{zz})^2+(\tau_{xx}-\tau_{zz})^2+6\left(\tau_{xy}^2+\tau_{yz}^2+\tau_{zx}^2\right)}{2}}$$

$$= \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}}$$

Specific gravity of a liquid:

$$s = \rho(\text{liquid}) / \rho(\text{H}_2\text{O})$$

Shear stress versus shear rate for a Newtonian fluid:

$$\tau = \mu \frac{\mathrm{d}V}{\mathrm{d}y} = \mu \dot{\gamma} \qquad \text{(M4.5)}$$

$$\tau = \mu \frac{\mathrm{d}u}{\mathrm{d}y} \qquad \text{(B2.3)}$$

Bulk modulus (fluid compressibility) equation:

$$E_{\mathsf{V}} = \rho \frac{\mathrm{d}p}{\mathrm{d}\rho} \tag{B2.7}$$

Speed of sound in a substance:

$$c = \sqrt{\frac{E_{\mathsf{V}}}{\rho}} \tag{B2.8}$$

Fluid acceleration equation:

$$\frac{\mathrm{d}\mathbf{V}}{\mathrm{d}t} = \frac{\partial \mathbf{V}}{\partial t} + u\frac{\partial \mathbf{V}}{\partial x} + v\frac{\partial \mathbf{V}}{\partial y} + w\frac{\partial \mathbf{V}}{\partial z} \tag{B2.10}$$

Fluid acceleration along a streamline:

$$\left(\frac{\mathrm{d}V}{\mathrm{d}t}\right)_{\text{tang.}} = \frac{\partial V}{\partial t} + V\frac{\partial V}{\partial s} \tag{B2.11}$$

Fluid acceleration normal to a curving streamline:

$$\left(\frac{\mathrm{d}V}{\mathrm{d}t}\right)_{\text{norm.}} = \frac{V^2}{R_c} \tag{B2.12}$$

Hydrostatic equilibrium equation:

$$\frac{\mathrm{d}p}{\mathrm{d}z} = -\rho g \tag{B2.15}$$

Hydrostatic pressure difference equation:

$$p_2 - p_1 = -\rho g\left(z_2 - z_1\right) \tag{B2.16}$$

$$\Delta P = \rho g_c \Delta h \tag{M2.2}$$

Conservation of mass for flow within a stream-tube:

$$\int_{A_2} \rho V_{2\mathrm{n}} \mathrm{d}A_2 - \int_{A_1} \rho V_{1\mathrm{n}} \mathrm{d}A_1 = -\frac{\partial}{\partial t}\int_{\mathscr{V}} \rho \mathrm{d}\mathscr{V} \qquad \text{(B2.20)}$$

Conservation of mass for flow within a stream-tube of constant volume:

$$A_2 V_2 = A_1 V_1 = Q \text{ (a constant)} \qquad \text{(B2.21)}$$

$$\dot{m}_{\mathrm{out}} = \dot{m}_{\mathrm{in}} \qquad \text{(M4.1)}$$

$$\left(\rho\dot{Q}\right)_{\mathrm{out}} = \left(\rho\dot{Q}\right)_{\mathrm{in}} \qquad \text{(M4.2)}$$

$$\dot{m} = \rho_{\mathrm{out}} V_{\mathrm{out}} A_{\mathrm{out}} = \rho_{\mathrm{in}} V_{\mathrm{in}} A_{\mathrm{in}}$$

Conservation of momentum for flow along a stream-line:

$$\rho\left(\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial s}\right)\mathrm{d}s = -\frac{\partial p}{\partial s}\mathrm{d}s - \rho g \mathrm{d}z \qquad \text{(B2.22)}$$

Bernoulli equation (conservation of momentum for steady flow along a stream-line):

$$p + \rho\frac{V^2}{2} + \rho g z = H \text{ (a constant)} \qquad \text{(B2.24)}$$

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 \qquad \text{(M4.27)}$$

Reynolds number criterion for laminar flow:

$$\mathrm{Re} = \frac{\rho V d}{\mu} < \mathrm{Re}_{\mathrm{crit}} \approx 2000 \tag{B2.35}$$

$$N_{\mathrm{Re}} = \frac{\rho D V}{\mu} \tag{M4.7}$$

Poiseuille flow velocity profile (laminar viscous flow in a circular tube):

$$u = -\frac{1}{4\mu}\frac{\mathrm{d}p}{\mathrm{d}x}\left(a^2 - r^2\right) \tag{B2.31a}$$

$$V = \frac{(P_1 - P_2)\left(R^2 - r^2\right)}{4\mu L} \tag{M4.8}$$

Poiseuille flow pressure drop:

$$\Delta p = \frac{32\mu L V}{d^2} \tag{B2.33}$$

Poiseuille flow entry length equation:

$$\frac{L_{\mathrm{e}}}{d} \approx 0.06\mathrm{Re} \tag{B2.36}$$

Mean kinetic energy of a particle:

$$\left\langle \frac{m v_x^2}{2} \right\rangle = \frac{k_{\mathrm{B}} T}{2}$$

Fick's law of diffusion:

$$J_D = -D_{AB}\frac{\mathrm{d}C_A}{\mathrm{d}x} \tag{M2.8}$$

Photon attenuation equation:

$$I = I_0\,\mathrm{e}^{-\mu z} \tag{B12.1}$$

$$\mathrm{I}_x = \mathrm{I}_0\,\mathrm{e}^{-\mu_x x} \tag{M8.13}$$

Radionuclide decay equation:

$$N = N_o\mathrm{e}^{-\lambda t} \tag{B13.2}$$

Physical half-life:

$$T_{\mathrm{p}1/2} = \log_{\mathrm{e}} 2/\lambda \tag{B13.2}$$

Acoustic intensity, pressure, velocity and impedance relations:

$$I = pv = Zv^2 = \frac{p^2}{Z}$$

Acoustic impedance:

$$Z = \rho c \tag{B12.15}$$

Pressure reflection coefficient:

$$R_P = \frac{P_r}{P_i} = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

Intensity reflection coefficient:

$$R_I = \frac{I_r}{I_i} = R_P^2$$

Intensity transmission coefficient:

$$T_I = \frac{I_t}{I_i} = 1 - R_I$$

Ultrasound attenuation equation:

$$I = I_o \mathrm{e}^{-\mu d} \qquad \text{(B12.17)}$$

Doppler frequency equation:

$$f_r = f_o + \Delta f \qquad \text{(B12.19)}$$

Doppler frequency shift:

$$\Delta f = \frac{-2v f_o}{c+v} \cos\theta \approx \frac{-2v f_o}{c} \cos\theta \qquad \text{(B12.18)}$$

Larmor equation:

$$\omega_o = \gamma B_o \qquad \text{(B12.9)}$$

$$f_R = \gamma B \qquad \text{(M8.24)}$$

T1 and T2 relaxation equations:

$$M_z = M\left(1 - \mathrm{e}^{-t/\tau_1}\right) \qquad \text{(M8.31)}$$

$$M_{xy} = M \mathrm{e}^{-t/\tau_2} \qquad \text{(M8.32)}$$

Spin echo sequence NMR signal strength:

$$S \approx N\,f(v)\left[e^{-TE/T2}\right]\left[1-e^{-TR/T1}\right] \qquad \text{(B12.10)}$$

THE END